Consumption of butterfish at various life stages by fishes of the Northeast US continental shelf

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Summary

Time series of butterfish (*Peprilus triacanthus*) consumption was estimated with evacuation rate models for 10 fish predators of the NE US continental shelf, 1973-2019. Annual removal of butterfish averaged approximately 3,300 MT per year across the shelf. Considering butterfish prey lengths, individuals from 1-20 cm were consumed with the majority of butterfish being 5-10 cm. These 5-10 cm butterfish constituted an average of 1,947 MT of the butterfish consumed per year.

Introduction

Fish food habits data from NEFSC bottom trawl surveys were evaluated for 10 predators (Table 1). From these data, diet composition of butterfish, per capita consumption, and the amount of butterfish removed by the predators were calculated. Combined with annual abundance estimates of these predators, annual butterfish consumption were summed independently across all predators as total annual consumption for butterfish.

Methods

Every predator that contained butterfish was identified. From that original list, a subset of the top-10 butterfish predators (85 % of all butterfish occurrences as prey) that were regularly encountered by the bottom trawl survey and sampled throughout the time series were included for estimating total consumption. Minimum sizes of predators for butterfish predation were derived from the NEFSC Food Habits Database (Table 1). Diet data were considered as one unit stock by including all bottom trawl survey strata.

Estimates were calculated on a seasonal basis (two 6-month periods) for each predator, and summed per year. Although food habits data collections for these predators started quantitatively in 1973 (Order Gadiformes only) and extends to the present (through 2019), not all of the predators considered here were sampled during the full extent of this sampling program. Stomach sampling for the non-Gadiformes considered here began in 1977 and extends through 2019. In fall 2017, due to survey vessel issues, sampling was limited to northern strata (Georges Bank and Gulf of Maine) and excluded the predators smooth dogfish, and spotted hake. For more details on the food habits sampling protocols and approaches, see Link and Almeida (2000), Smith and Link

(2010), and Smith and Rowe (2021). This sampling program was part of the NEFSC bottom trawl survey program; further details of the survey program can be found in Azarovitz (1981), NEFC (1988), Reid et al. (1999), and Politis et al. (2014).

Basic Diet Data

Mean amounts of butterfish eaten ($D_{i,t}$; as observed from diet sampling) for each predator (i), and temporal scheme (t, fall or spring each year) were weighted by the number of fish at length per tow and the total number of fish per tow as part of a two-stage cluster design (similar to Link and Almeida 2000; Latour et al. 2007). These means included empty stomachs, and units for these estimates are in grams (g).

Numbers of Stomachs

The adequacy of stomach sample sizes were assessed with trophic diversity curves by estimating the mean cumulative Shannon-Wiener diversity of stomach contents plotted as a function of stomach number. The order of stomachs sampled was randomized 100 times, and cumulative diversity curves were constructed for each species focusing on the early 1980s when stomach sampling effort was generally lowest for the entire time series. The criteria for asymptotic diversity was met when the slope of the three proceeding mean cumulative values was ≤ 0.1 which was similar to previous fish trophic studies (e.g. Koen Alonso et al. 2002; Belleggia et al. 2008; Braccini 2008). A minimum sample size equal to 25 stomachs for each predator per year-season emerged as the general cutoff for these asymptotes. Annual estimates of diet compositions of butterfish were estimated for each predator and season. For all predators, mean amounts of butterfish consumed ($D_{i,t}$) were not averaged between years with zero stomachs containing butterfish.

Consumption Rates

To estimate per capita consumption, the gastric evacuation rate method was used (Eggers 1977; Elliott and Persson 1978). There are several approaches for estimating consumption, but this approach was chosen as it was not overly simplistic (as compared to % body weight; Bajkov 1935) or overly complex (as compared to highly parameterized bioenergetics models; Kitchell et al. 1977). Additionally, there has been extensive use of these models (Durbin et al. 1983; Ursin et al 1985; Pennington 1985; Overholtz et al. 1999, 2000; Tsou and Collie 2001a, 2001b; Link and Garrison 2002; Link et al. 2002; Overholtz and Link 2007; Smith et al 2016; Smith and Smith 2020). Units are in g year^{-1}.

Using the evacuation rate model to calculate consumption requires two variables and two parameters. The seasonal, daily per capita consumption rate of butterfish, $C_{i,t}$ is calculated as:

$$C_{i,t} = 24 \cdot E_{i,t} \cdot D_{i,t} \quad ,$$

where 24 is the number of hours in a day. The evacuation rate $E_{i,t}$ is:

$$E_{i,t} = \alpha e^{\beta T_{i,t}} \quad ,$$

and is formulated such that estimates of mean butterfish eaten ($D_{i,t}$) and ambient temperature ($T_{i,t}$) as stratified mean bottom temperature associated with the presence of each predator from the NEFSC bottom trawl surveys (Taylor and Bascuñán 2000; Taylor et al. 2005) are the only data required. The parameters α and β were set as 0.002 and 0.115 for the elasmobranch predators respectively and 0.004 and 0.115 for the teleost predators respectively (Tsou and Collie 2001a, 2001b, Overholtz et al. 1999, 2000).

To evaluate the performance of the evacuation rate method for calculating consumption, a sensitivity analysis had been previously executed (NEFSC 2007). The ranges of α and β within those reported for the literature do not appreciably impact consumption estimates (< half an order of magnitude), nor do ranges of T which were well within observed values (<< quarter an order of magnitude). An order of magnitude change in the amount of food eaten linearly results in an order of magnitude change in per capita consumption. Variance about any particular species of predator stomach contents has a CV of ~50%. Estimates of abundance, and changes in estimates thereof, are likely going to dominate the scaling of total consumption by a broader range of magnitudes than the parameters and variables requisite for the evacuation method of estimating consumption.

Fish Predator Abundance Estimation

The scaling of total consumption requires information on predator population abundance of sizes actively preying on butterfish (Table 1). The minimum predator size of butterfish predation was determined by querying the NEFSC Food Habits Database. Population abundance estimates were made by scaling the stratified mean predator abundance per tow by the area swept for the fall season for each year for butterfish predators (Table 2). Catchability (q) was assumed to equal 1.0 for all predators.

Scaling Consumption

Following the estimation of consumption rates for each predator (i), and temporal (t) scheme they were scaled up to a seasonal estimate ($C'_{i,t}$) by multiplying the number of days in each half year:

$$C'_{i,t} = C_{i,t} \cdot 182.5 \qquad .$$

These were then summed to provide an annual estimate, $C'_{i,\,year}$:

$$C'_{i,year} = C_{i,fall} + C_{i,spring} \quad .$$

and were then scaled by the annual abundance to estimate a total annual amount of butterfish removed by predator, $C_{i,year}$:

$$C_{i,year} = C'_{i,year} \cdot N_{i,year} \qquad .$$

The final butterfish consumption time series was 1973-2019. The total amount of butterfish removed ($C_{i,year}$) were then summed across all i predators to estimate a total amount of butterfish removed, C_{year}:

$$C_{year} = \textstyle\sum_i C_{i,year} \qquad .$$

The total consumption of butterfish per predator and total amount of butterfish removed by all predators were presented as thousands of metric tons year^{-1}.

Uncertainty

Error associated with consumption was quantified with a randomization approach. For total consumption (summed across predators), gamma distributions were assumed for each input parameter (i.e. $D_{i,t}$, α, β, $t_{i,t}$, $N_{i,t}$) with moment matching shape and rate to mean and standard deviation to generate 1000 observations per input parameter per predator, season and year. This permitted estimates of 95% confidence intervals for a mean total consumption per year from distributions of consumption across all predators for butterfish.

Prey lengths

The proportions of butterfish prey lengths were estimated across all years and predators due to the low average numbers of lengths measured each year (43). When applied to the annual total consumption estimates across predators, this offers an understanding of what prey sizes were targeted by fish predation and the quantity of removal.

Results and Conclusions

Total consumption of butterfish by fish predators was variable throughout 1973-2019, but predation was generally low over time relative to other forage species of particular concern (Smith and Rowe 2021). The minimum amount of butterfish removed was equal to zero MT year^{-1} for 3 individual years throughout the time series, and a maximum amount of approximately 26,000 MT in 2016 (Fig. 1; Table 3). Time series means of total consumption of butterfish were 3,327 MT year^{-1} (Fig. 2; Table 4). These results suggest low amounts of consumption by these predators and indicate that butterfish is not often identified in fish stomachs of the NE US continental shelf. It would be worthwhile to look into more precise techniques for identifying butterfish (i.e molecular) in fish stomach contents as even minor amounts of digestion can render small individuals difficult to identify macroscopically.

Butterfish prey lengths

The proportions of butterfish prey lengths per 5 cm bins were < 5 cm: 0.09; 5-10 cm: 0.58; 11-15 cm: 0.29; 16-20 cm: 0.04. Consumption of butterfish was highest for prey sizes 5-10 cm and averaged 1,947 MT per year (Fig 3; Table 5).

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Tables

Table 1. Regularly-sampled predators of butterfish (*Peprilus triacanthus*; non-shaded), their minimum size (cm) of butterfish predation, and percent frequency of occurrence (% FO) of butterfish predation from the NEFSC Food Habits Database. Shaded rows denote excluded predators with % FO ≥ 1, but have sporadic or limited sampling.

Common Name	Scientific Name	Size (cm)	% FO
Bluefish	*Pomatomus saltatrix*	12	24.5
Fourspot flounder	*Paralichthys oblongus*	21	2.3
Goosefish	*Lophius americanus*	10	9.9
Pollock	*Pollachius virens*	35	2.3
Silver hake	*Merluccius bilinearis*	8	12.9
Spiny dogfish	*Squalus acanthias*	32	15.7
Smooth dogfish	*Mustelus canis*	42	3.8
Spotted hake	*Urophycis regia*	22	2.3
Summer flounder	*Paralichthys dentatus*	29	8.9
Winter skate	*Leucoraja ocellata*	50	2.5
Weakfish	*Cynoscion regalis*	28	2.5
Buckler dory	*Zenopsis conchifera*	14	2.2
Striped bass	*Morone saxatilis*	55	1.4
Atlantic cod	*Gadus morhua*	49	1.0
Sea raven	*Hemitripterus americanus*	22	1.0

Table 2. Time series of population abundance (numbers of individuals) for butterfish predators. Years without sampling denoted by “NA”.

year	Bluefish	Fourspot flounder	Goosefish	Pollock	Silver hake	Smooth dogfish	Spiny dogfish	Spotted hake	Summer flounder	Winter skate
1973	24,718,455	41,568,002	10,823,430	11,467,376	168,508,322	8,978,460	127,743,656	79,913,774	8,644,817	26,393,106
1974	16,066,957	19,481,817	4,105,715	17,971,248	622,057,393	9,391,519	43,270,628	40,362,152	10,465,157	10,946,279
1975	10,957,681	33,805,068	8,697,091	15,287,740	389,928,020	19,575,412	183,773,379	45,998,084	17,083,055	4,540,593
1976	36,251,321	42,108,715	5,650,484	44,754,910	513,093,911	15,811,855	96,911,007	55,978,096	8,197,728	8,662,724
1977	40,720,883	37,100,289	6,366,668	29,085,733	426,276,810	23,060,078	58,737,348	30,822,601	14,767,786	26,832,658
1978	9,395,144	41,747,796	7,301,249	18,330,039	366,323,028	9,306,641	338,772,603	121,302,073	4,183,685	11,447,361
1979	20,105,008	66,420,974	9,259,135	15,460,854	246,884,541	15,003,601	280,205,403	114,206,324	10,362,869	17,040,066
1980	29,477,589	58,164,083	10,050,291	6,801,076	339,560,609	5,903,334	62,585,922	135,363,827	9,326,300	12,640,285
1981	84,865,089	83,645,919	10,753,417	16,336,213	291,206,494	6,489,196	216,728,734	51,109,997	7,872,750	22,427,891
1982	25,787,955	72,247,916	6,921,097	15,715,192	385,193,656	9,288,139	90,297,358	88,163,467	10,873,120	49,030,931
1983	20,747,085	94,408,854	9,763,259	16,411,038	360,288,520	4,588,965	208,563,431	30,904,861	11,544,752	24,379,511
1984	34,320,076	89,305,784	5,459,844	7,696,759	217,343,151	7,329,521	180,154,991	125,233,535	7,025,631	40,023,238
1985	19,193,899	67,961,472	6,938,931	6,070,194	658,287,599	8,003,142	198,018,591	37,520,773	6,718,440	32,751,814
1986	31,098,952	59,765,394	6,226,970	2,827,566	443,999,706	7,608,939	132,293,075	190,709,312	6,045,921	58,122,816
1987	9,802,636	76,282,746	6,495,293	4,897,076	225,930,586	4,514,175	214,991,993	103,589,974	2,946,043	38,879,989
1988	20,828,114	38,983,630	5,126,754	51,306,778	389,170,084	4,985,969	139,661,944	168,710,496	3,446,181	34,072,313
1989	78,659,433	81,132,567	6,685,020	12,887,454	422,645,297	4,998,067	96,317,361	48,972,467	3,094,490	24,667,189
1990	9,782,404	65,792,260	6,569,062	6,817,974	567,631,124	6,423,857	92,729,575	71,608,865	3,139,024	25,704,221
1991	13,068,181	37,632,737	9,856,184	5,289,806	739,050,019	2,670,770	120,410,965	130,632,389	5,726,467	24,219,602
1992	9,975,533	46,620,562	7,626,801	9,328,996	646,967,524	3,243,503	235,845,240	48,487,787	8,977,038	20,634,386
1993	3,270,877	49,205,023	7,195,931	3,732,314	302,754,214	4,155,930	98,525,174	53,032,188	2,639,095	18,693,517
1994	7,969,089	45,552,988	9,993,676	3,548,319	249,931,972	3,382,389	118,673,952	140,151,337	5,108,287	22,537,037
1995	10,817,936	43,382,927	7,316,608	8,922,549	848,558,795	4,735,815	139,301,692	93,712,400	7,481,156	21,303,181
1996	9,125,747	40,261,958	5,805,962	12,232,509	199,192,055	6,524,317	281,432,258	359,978,455	6,152,808	20,447,765
1997	5,660,125	47,512,870	5,411,106	11,865,739	300,010,239	3,754,637	147,228,225	57,278,749	9,803,537	17,372,298
1998	10,003,320	55,711,968	6,263,115	25,374,772	1,042,874,698	11,755,554	150,258,221	200,828,620	20,046,063	22,382,841
1999	20,793,000	60,279,136	8,599,419	20,460,731	798,444,914	14,010,979	93,754,515	76,754,419	10,980,162	20,824,303
2000	8,969,135	55,423,965	11,626,802	14,294,033	764,555,183	4,855,869	103,465,536	248,669,386	13,013,436	25,538,186
2001	11,593,766	47,368,612	9,371,970	11,288,107	524,011,183	13,334,527	171,295,645	117,874,462	10,576,921	22,438,264
2002	9,822,797	99,833,799	10,550,231	20,996,147	377,607,787	8,149,384	174,056,109	167,206,384	12,569,101	24,065,138
2003	25,734,664	59,717,627	12,548,042	66,171,534	685,608,141	12,842,913	109,924,282	669,173,715	9,927,436	16,047,770
2004	12,206,562	40,567,660	5,873,467	30,853,034	214,984,904	11,016,993	193,852,804	1,069,290,928	15,582,276	21,398,515
2005	21,099,934	78,465,983	8,082,923	20,165,217	107,032,072	13,873,622	225,928,331	97,240,474	11,835,499	16,241,642
2006	23,722,436	71,036,902	8,930,900	14,007,905	219,124,485	8,978,251	161,593,635	91,039,340	12,950,873	24,956,675
2007	11,330,877	44,222,695	6,156,750	2,105,790	261,317,620	14,413,613	203,774,574	51,812,887	12,428,967	22,833,286
2008	14,319,257	60,847,935	8,033,733	9,559,974	250,739,963	7,336,698	137,358,902	80,952,214	8,639,748	37,596,771
2009	14,685,365	49,452,379	3,419,227	2,852,876	380,424,058	6,777,739	198,698,622	153,201,525	14,018,583	30,858,604
2010	12,746,402	67,097,515	4,107,577	9,241,317	834,121,572	7,240,606	197,083,461	81,180,871	8,874,445	39,203,083
2011	11,193,819	52,228,663	5,073,421	32,178,757	494,776,065	6,210,731	267,341,998	136,973,948	13,402,344	44,290,149
2012	6,382,971	52,851,284	3,434,986	9,633,694	1,008,937,269	8,209,048	434,647,912	112,936,544	10,515,215	53,910,717
2013	16,905,996	37,926,234	4,251,699	14,562,219	997,833,579	3,955,611	441,262,165	44,672,993	6,464,351	46,413,366
2014	4,168,353	47,706,946	4,429,341	97,482,757	530,797,080	3,339,978	371,808,725	144,057,445	9,320,099	19,150,010
2015	2,790,306	49,118,349	13,693,658	29,190,174	496,663,892	7,745,409	219,379,052	77,165,946	7,924,367	24,581,639
2016	2,587,237	37,499,610	9,340,343	15,377,318	748,107,704	11,446,708	375,269,497	133,429,672	9,373,986	19,695,712
2017	NA	11,843,137	4,869,632	7,655,062	625,062,919	329,286	240,535,872	3,785,669	1,187,337	15,438,071
2018	6,895,423	29,925,945	5,947,446	5,329,557	583,078,129	14,740,780	162,652,981	194,867,984	7,329,983	25,882,258
2019	5,679,125	27,817,618	6,824,745	9,474,812	833,259,869	8,437,483	253,839,381	219,248,928	6,282,179	56,915,807

Table 3. Time series data of butterfish consumption (000s MT) by 10 fish predators.

year	Bluefish	Fourspot flounder	Goosefish	Pollock	Silver hake	Smooth dogfish	Spiny dogfish	Spotted hake	Summer flounder	Winter skate
1973	0.000	0.000	0.000	0.000	1.455	0.000	0.000	0.000	0.000	0.000
1974	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.094	0.000	0.000	0.000	0.000
1978	1.819	0.007	0.000	0.000	0.000	0.172	0.002	0.000	0.000	0.000
1979	0.785	0.000	0.693	0.000	0.000	0.147	0.000	0.000	0.000	0.000
1980	0.325	0.000	1.099	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	4.822	0.000	0.000	0.000	0.088	0.000	0.202	0.000	0.079	0.000
1982	5.743	0.000	2.665	0.000	2.394	0.000	0.126	0.000	0.000	0.000
1983	0.000	0.000	0.000	0.000	0.000	0.000	0.794	0.000	0.000	0.000
1984	2.162	0.000	0.170	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	1.799	0.000	0.000	0.016	0.341	0.000	2.691	0.000	0.000	0.000
1986	0.265	0.008	0.000	0.000	1.821	0.000	0.023	0.000	0.205	0.000
1987	0.290	0.000	0.000	0.000	0.111	0.000	0.039	0.000	0.019	0.000
1988	0.091	0.136	0.000	0.000	0.333	0.001	0.020	0.000	0.065	0.000
1989	5.230	0.000	0.000	0.000	0.164	0.000	0.056	0.091	0.222	0.000
1990	0.487	0.000	0.000	0.000	7.142	0.000	0.011	0.054	0.393	0.186
1991	0.288	0.000	0.567	0.000	0.634	0.026	0.038	0.000	0.083	0.407
1992	0.052	0.039	0.000	0.000	0.186	0.005	0.267	0.499	0.105	0.020
1993	0.410	0.000	0.120	0.000	0.256	0.000	1.003	0.027	0.069	0.227
1994	0.000	0.120	0.018	0.000	0.711	0.000	0.076	0.538	0.017	0.041
1995	0.000	0.000	0.038	0.038	0.120	0.216	0.099	0.079	0.026	0.000
1996	0.126	0.000	0.000	0.831	0.033	0.008	0.094	0.000	0.012	0.000
1997	1.085	0.034	0.504	0.434	1.429	0.034	2.214	0.000	0.095	0.012
1998	0.073	0.240	0.011	0.656	1.263	0.000	0.148	0.221	0.115	0.052
1999	3.362	0.000	0.071	1.929	0.957	0.776	0.251	0.019	0.143	0.019
2000	0.412	0.000	1.317	0.171	0.000	0.000	0.203	0.521	0.178	0.000
2001	0.289	0.063	0.227	0.307	0.437	0.256	0.008	0.543	0.077	0.000
2002	0.004	0.000	0.000	0.000	0.146	0.025	1.504	0.000	0.147	0.000
2003	2.945	0.000	0.593	0.000	0.050	0.229	0.214	0.000	0.026	0.000
2004	0.203	0.428	0.069	0.000	0.000	0.007	0.903	0.000	0.256	0.000
2005	0.088	0.008	0.011	0.000	0.021	0.011	0.014	0.094	0.771	0.141
2006	4.171	0.000	0.188	0.000	0.000	0.000	6.952	0.000	0.096	0.073
2007	0.057	0.000	0.099	0.000	0.514	0.000	0.249	0.000	0.062	0.011
2008	0.315	0.106	0.000	0.000	0.156	0.078	0.334	0.000	0.194	0.114
2009	10.966	0.036	0.326	0.000	0.726	0.000	0.147	0.345	0.356	0.000
2010	0.174	0.000	0.265	0.000	0.094	0.086	0.253	0.000	0.134	0.335
2011	4.332	0.000	1.183	0.000	0.043	0.000	0.151	0.000	0.139	0.133
2012	0.072	0.032	0.063	0.000	0.439	0.006	1.341	0.554	0.067	0.019
2013	0.128	0.178	0.216	0.000	0.270	0.000	0.000	0.000	0.069	0.152
2014	0.127	0.000	0.238	0.000	0.121	0.000	11.417	0.777	0.003	0.000
2015	0.178	0.034	0.382	0.038	0.232	0.000	0.018	0.000	0.161	0.000
2016	0.000	0.000	0.126	0.000	7.401	0.175	18.088	0.000	0.103	0.099
2017	NA	0.010	0.027	0.000	0.010	0.000	0.000	0.000	0.000	0.000
2018	1.971	0.161	0.521	0.000	2.346	0.000	0.165	0.000	0.035	0.478
2019	0.053	0.000	0.022	0.000	0.404	0.000	0.000	0.000	0.003	0.000

Table 4. Time series data of mean total consumption of butterfish (000s MT) and lower (lci) and upper (uci) 95% ci.

year	mean	lci	uci
1973	1.583	0.104	6.298
1974	0.000	0.000	0.000
1975	0.000	0.000	0.000
1976	0.000	0.000	0.000
1977	0.106	0.001	0.548
1978	0.218	0.007	1.135
1979	0.841	0.063	3.466
1980	1.211	0.027	5.471
1981	0.294	0.014	1.215
1982	11.984	3.105	32.077
1983	0.815	0.024	4.209
1984	0.188	0.003	0.789
1985	3.469	0.205	13.957
1986	2.348	0.287	8.529
1987	0.181	0.021	0.622
1988	0.617	0.132	1.792
1989	0.603	0.165	1.552
1990	8.605	1.385	28.508
1991	1.884	0.507	4.777
1992	1.365	0.429	3.519
1993	2.178	0.617	6.316
1994	1.658	0.577	4.259
1995	0.696	0.245	1.598
1996	1.219	0.159	5.235
1997	6.567	2.080	19.322
1998	2.903	1.031	6.625
1999	8.356	2.082	27.304
2000	2.999	1.046	6.793
2001	2.355	0.963	5.111
2002	2.195	0.241	9.603
2003	4.718	1.111	16.061
2004	1.864	0.474	5.862
2005	1.340	0.202	5.098
2006	12.167	1.811	42.300
2007	1.075	0.254	2.800
2008	1.112	0.280	3.135
2009	2.210	0.811	5.234
2010	1.548	0.486	3.922
2011	6.672	1.847	20.079
2012	2.796	0.592	9.552
2013	1.150	0.372	2.572
2014	13.228	1.259	52.338
2015	1.194	0.351	3.045
2016	30.769	4.031	131.137
2017	0.057	0.012	0.159
2018	6.490	1.906	16.006
2019	0.546	0.098	1.721

Table 5. Time series data of total consumption of butterfish (000s MT) by prey size (cm).

year	<5	5-10	11-15	16-20
1973	0.141	0.926	0.454	0.061
1974	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000
1977	0.009	0.062	0.030	0.004
1978	0.019	0.127	0.063	0.008
1979	0.075	0.492	0.241	0.032
1980	0.108	0.709	0.348	0.046
1981	0.026	0.172	0.084	0.011
1982	1.070	7.015	3.440	0.459
1983	0.073	0.477	0.234	0.031
1984	0.017	0.110	0.054	0.007
1985	0.310	2.031	0.996	0.133
1986	0.210	1.374	0.674	0.090
1987	0.016	0.106	0.052	0.007
1988	0.055	0.361	0.177	0.024
1989	0.054	0.353	0.173	0.023
1990	0.769	5.037	2.470	0.329
1991	0.168	1.103	0.541	0.072
1992	0.122	0.799	0.392	0.052
1993	0.195	1.275	0.625	0.083
1994	0.148	0.970	0.476	0.063
1995	0.062	0.408	0.200	0.027
1996	0.109	0.714	0.350	0.047
1997	0.587	3.844	1.885	0.251
1998	0.259	1.699	0.833	0.111
1999	0.746	4.891	2.399	0.320
2000	0.268	1.755	0.861	0.115
2001	0.210	1.379	0.676	0.090
2002	0.196	1.285	0.630	0.084
2003	0.421	2.761	1.354	0.181
2004	0.166	1.091	0.535	0.071
2005	0.120	0.784	0.385	0.051
2006	1.087	7.122	3.493	0.466
2007	0.096	0.629	0.309	0.041
2008	0.099	0.651	0.319	0.043
2009	0.197	1.293	0.634	0.085
2010	0.138	0.906	0.445	0.059
2011	0.596	3.905	1.915	0.255
2012	0.250	1.636	0.803	0.107
2013	0.103	0.673	0.330	0.044
2014	1.181	7.743	3.797	0.506
2015	0.107	0.699	0.343	0.046
2016	2.748	18.010	8.833	1.178
2017	0.005	0.033	0.016	0.002
2018	0.580	3.799	1.863	0.248
2019	0.049	0.320	0.157	0.021

Figures

Figure 1. Time series of butterfish consumption (000s MT) by 10 fish predators.

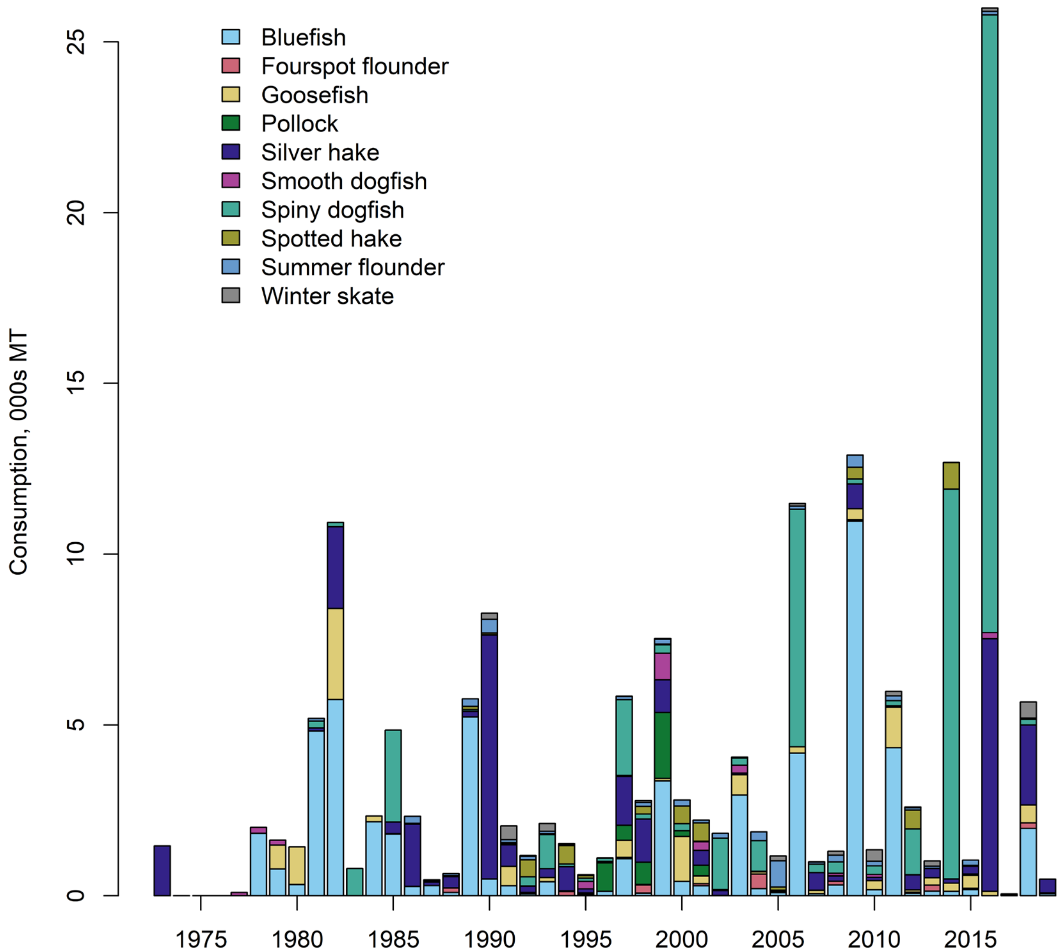

Figure 2. Time series of total consumption of butterfish (000s MT). Shading denotes 95% ci.

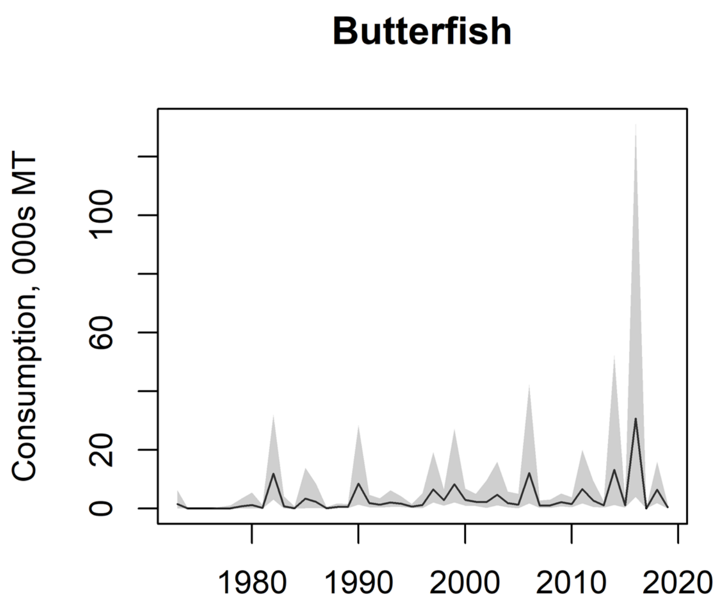

Figure 3. Time series of butterfish consumption (000s MT) by prey size (cm).