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PROPORTIONAL STOCK DENSITY INDEX— IS IT A USEFUL TOOL FOR ASSESSING FISH POPULATIONS IN NORTHERN LATITUDES?

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57

ABSTRACT

The length-frequency index, Proportional Stock Density (PSD), has been proposed as a method to evaluate the size structure of fish populations and communities. The results of this method of appraising the size structure of a fish population and its relative well-being or balance may be impacted by several factors including fish distribution and behavior in relation to the method of collection and the impact of variable year class strength on the value determined in any one year. In Escanaba Lake, Wisconsin, PSD's for walleyes (calculated from both fyke net and angling catches) from 1956-82 varied widely due to methods of sampling and variable year class strength. I recommend that the use of PSD's or other length-frequency indices to evaluate size structure in a fish population or community be used with caution and only when combined with age-frequency and growth data.

CONTENTS

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INTRODUCTION

The use of length-frequency indices of fish stocks to evaluate the state of balance or structure of cool water fish populations and communities has been proposed by Anderson (1976). He recommends using the Proportional Stock Density (PSD) index. All that is needed to calculate this index is a definition of minimum lengths for stock- and quality-sized fish and a length-frequency distribution of the stock.

The objectives of this paper are: (1) to examine the validity of using Proportional Stock Density to evaluate the structure of the Escanaba Lake walleye (*Stizostedion vitreum vitreum*) population over a 27-year period, (2) to analyze the impacts of various parameters on Escanaba Lake walleye PSD's, and (3) to compare PSD's calculated using walleyes sampled by two different methods (fyke net and angling).

STUDY AREA AND METHODS

Escanaba Lake is a 293-acre soft water drainage lake located in north central Wisconsin (latitude 46°04', longitude 89°35') on undeveloped state-owned land in the Northern Highland State Forest. Since 1946, a compulsory complete creel census has been in effect for Escanaba Lake. All anglers are required to obtain a free fishing permit (at the contact station located at the only access point) prior to fishing and to return the permit along with any fish which are caught and kept to the checking station at the completion of their angling trip. Detailed morphological and chemical data for Escanaba Lake are found in Serns (1982a).

There are at least 24 species of fish in Escanaba Lake (Kempinger et al. 1975). Important species in the sport catch in recent years have included: walleye, northern pike (*Esox lucius*), muskellunge (*Esox masquinongy*), yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*), and black crappie (*Pomoxis nigromaculatus*).

Since 1946, the walleye sport fishery of Escanaba Lake has been unregulated by size, bag, or season restrictions. The lake has received an average annual fishing pressure of 17,400 hours for the period of 1946-82. Annual angler exploitation rates for walleyes averaged 25% from 1953-82 (Kempinger et al. 1975; Serns, unpubl. data).

Walleyes were captured each spring shortly after ice-out and during spawning from 1956-69 and in 1972, 1974, 1977, and from 1979-82 in 1-inch[2] mesh fyke nets. Each fish was measured to the nearest 0.1 inch total length, jaw tagged and/or fin clipped, and returned to the lake. All walleyes harvested by anglers during the period of 1956-82 were measured to the nearest 0.1 inch at the contact station.

Proportional Stock Densities (PSD) were calculated for both angler-caught and fyke-netted walleyes for the period of 1956-82 when possible (in some years no spring fyke netting was done) using the formula:

$$\text{PSD (\%)} = \frac{\text{number} \geq \text{quality size} \times 100}{\text{number} \geq \text{stock size}}$$

For walleyes, stock and quality sizes have been defined as 10 and 15 inches, respectively (Anderson and Weithman 1978). The relationship between PSD values and various parameters was investigated by regression analysis.

RESULTS

The number of walleyes longer than 10 and 15 inches and PSD's for fish collected in fyke nets and by angling during the period 1956-82 are shown in Table 1. The mean ($\pm$ SD) and coefficient of variation (CV) of the PSD values by fyke netting were 51 $\pm$ 18 and 35, respectively, while the mean ($\pm$ SD) and CV values from angling in May were 34 $\pm$ 16 and 47, respectively. The same values for angling data for the entire open water period were 25 $\pm$ 12 and 48. The range in PSD values from the fyke net samples was 12-83, while the PSD range from the angling data was 9-63 for May and 13-55 for the entire open water period (Table 1). PSD values calculated from fyke netting samples and those determined from May angling were highly correlated (r = 0.634, $P < 0.01$). However, there was no relationship between fyke net PSD's and PSD's from angling during the entire open water period (r = 0.224, $P > 0.05$).

Mark-recapture estimates of the number of young-of-the-year walleyes in Escanaba Lake have been made from 1958-82 (Table 2). It seems logical that the occurrence of a large natural year class may reduce PSD values when that age group recruits to stock size. Growth data for walleyes in Escanaba Lake (Serns 1984) indicated that walleyes would recruit into the stock size between ages II and III (in their 3rd summer of life). Therefore, to determine the effect of natural year class strength on PSD values, simple correlation coefficients were between fingerling walleye densities calculated for the relationship between fingerling walleye densities and PSD's from fyke nets 2 and 3 years later. These regression analyses indicated negative but nonsignificant ($P > 0.05$) relationships between fingerling density and PSD 2 years later (r = -0.239) and fingerling density vs. PSD 3 years later (r = -0.453) (Table 3). Correlation coefficients were not significant ($P >$ 0.05) for the relationship between fingerling density and PSD (May) 2 years later (r = -0.195) and the relationship between fingerling density and PSD (entire open water period) 2 years (r = -0.244) and 3 years (r = -0.352) later (Table 3). There was a significant ($P < 0.05$) negative relationship however between walleye fingerling density and May angling PSD values 3 years later (r = -0.494).

Growth of walleyes was not related to PSD values as indicated by regression analyses of mean annual growth increments between ages III and IV and ages IV and V (Table 2) vs. both fyke net and angling PSD's (May or entire open water season) (Table 3).

There was a significant negative relationship ($P < 0.05$) between angling PSD's (entire open water season) and walleye catch/angler-hour (Table 2). However, fyke net PSD's and angler catch rates were not related nor were angling PSD's from May related to catch/effort data (Table 3).

DISCUSSION

The assertion that PSD's or some other length-frequency index measured at one point in time will adequately determine the relative well-being or balance of a fish population or community does not adequately account for variables affecting PSD estimates. Factors other than the balance of the population can influence PSD's. Proportional Stock Density estimates for walleyes determined from spring fyke net samples are influenced by the timing of the netting in relation to walleye spawning activity. If the netting is conducted at the beginning or end of the spawning period, the catch will be biased toward males, which mature at an earlier age and smaller size and grow at a lower rate than females. Therefore, this phenomenon would tend to reduce PSD values. If the netting is done in the middle or "peak" of the spawning period, more females will be caught in relation to males and the PSD's will be higher.

Proportional Stock Density values determined for angler catches of walleyes will tend to be lower than those from fyke net samples because previous research has shown that younger (smaller) walleyes are more vulnerable to angling than older (larger) ones (Serns and Kempinger 1981). Mean PSD's from fyke net samples (51) were twice those from angling samples collected throughout the open water period (25) and 1.5 times higher than angling PSD's for the month of May (34). According to Anderson and Weithman (1978), the suggested range of PSD's for walleyes is from 30-60%. The PSD's from fyke net samples in Escanaba Lake were within this range in 20 of the 21 years (95%) for which data are available. However, if we examine the catch by anglers in May and during the entire open water period, the PSD values are within the suggested range in only 16 of 27 (59%) and 7 of 27 (26%) years, respectively. This shows that the method and time of sampling greatly affects PSD estimates regardless of the actual size structure of a population. Therefore PSD estimates from data casually collected are likely to be of little real use.

There was no correlation between PSD values determined from fyke netting and angling for the entire open water season although fyke net PSD's were closely related to May angling PSD's. The significant negative correlation between angling, PSD's (entire open water period) and number of walleyes harvested per angler-hour is a reflection of the higher vulnerability to angling of the smaller walleyes previously reported for Escanaba Lake walleyes (Serns and Kempinger 1981). When a large walleye year class recruits to the stock size, the PSD values are deflated and angler harvest rates increase because of the recruitment of the year class into the size range vulnerable to angling.

There can be great annual variability in PSD values determined from both fyke net and angling samples, indicating that a sample at one point in time with one method of collection may be relatively meaningless in determining the "balance" of a population. Fyke net PSD's in Escanaba Lake exhibited a one-year increase from 23.5 in 1959 to 74.4 in 1960 while open water angling PSD's declined over a one-year period from 54.5 in 1960 to 18.7 in 1961. These large fluctuations in PSD's from one year to the next could be the result of the sampling problems mentioned earlier or the recruitment of a large year class to either the stock size or quality size. The negative correlation coefficients for all but 1 of 6 relationships between fingerling densities and PSD's 2 and 3 years later indicates that a large year class would tend to deflate the PSD values when they recruit into the stock size range ($\geq$ 10 inches).

It could be argued that populations which are in "balance" would tend not to have the potential for large annual variabilities in year class strength; however, several studies over a broad geographical range of the northern United States have shown this phenomenon to be the rule rather than the exception (Johnson 1961, Forney 1976, Busch et al. 1975, Carlander and Payne 1977, Chevalier 1977, Serns 1982a). Such factors as variability of spring water temperatures, rate of increase in spring water temperatures, water levels, wind velocities, and young-of-the-year yellow perch abundance have been implicated as important factors determining the strength of walleye natural year classes. Several studies have also shown no correlation between brood stock size and year class strength (Smith and Krefting 1953, Schneider and Leach 1977, Smith 1977, Serns 1982a), indicating that a large, "stable" population of adults is no guarantee of a strong year class to maintain that population's "balance." Large variability in year class strength attributed to abiotic factors has also been reported for yellow perch (Clady 1976, Eshenroder 1977), smallmouth bass (Micropterus dolomieui) (Shuter et al. 1980, Serns 1982b), and largemouth bass (Micropterus salmoides) (Kramer and Smith 1962) in the north central United States and Canada. The analysis of the relationship between spawner density and reproductive success is confounded by the possible masking of any positive relationship between the two variables by the overriding impact of environmental and biological factors on year class strength (Beddington and May 1977, Serns 1982a). It has been well demonstrated that at some threshold level of spawner density, despite the influence of other factors, there is a direct relationship between spawners and year class abundance (Beddington and May 1977, Skud 1982).

Anderson (1980) reported a positive relationship between PSD's and growth of largemouth bass. Because of the impact of large year classes on PSD's when they recruit to stock size, it is doubtful that there would be a relationship between PSD's and growth of adult fish unless the fish entering the stock size range would be directly competing for a limited food resource that was also utilized by the adult (quality) fish. For walleyes in Escanaba Lake there was no correlation between growth and PSD's determined from either fyke netting or angling samples. In Escanaba Lake there may not have been much direct competition for a limited food resource between stock- and quality-sized walleyes. Parsons (1971) reported that as walleyes grew, the preferred size range of their prey increased, indicating that there may be little overlap in the food habits of small vs. large walleyes. Carline et al. (1984) evaluated the relative effects of growth, mortality, and recruitment on largemouth bass PSD's using computer simulations. They found that in medium to large impoundments recruitment was likely to have more influence on PSD than either growth or mortality.

I agree with Anderson (1976) that there is a management need for a simple, straightforward index which can be used to assess the size structure of a fish population and determine its well-being in relation to other populations. The development of the PSD index is a positive move in that direction. However, this paper illustrates how factors such as gear type and time of sampling may influence PSD values determined for one population. Variable year class strength may also have a profound influence on length-frequency distributions and may result in large annual differences in PSD values determined for the same population. Managers must be cognizant of such influences when examining length distribution data and calculating PSD.

It is likely that because of the large variability in year class strength attributed to abiotic factors and evident for several species in the northern United States and Canada, the use of the Proportional Stock Density index for evaluating "balance" has not been widely used by fisheries biologists in this region. Unless the PSD index (or something similar) is analyzed with additional information such as age-frequency and age-growth data, I doubt that it alone will be a particularly useful management tool for evaluating fish communities in the northern United States and Canada.

TABLE 1. Proportional Stock Density (PSD) values for walleyes captured in fyke nets (spring), and by angling in May and during the entire open water period, 1956-82.

	Fyke Net			Angling (May)			Angling (Open Water)		
Year	10+ inches	15+ inches	PSD (%)	10+ inches	15+ inches	PSD (%)	10+ inches	15+ inches	PSD (%)
1956	1,345	526	39	358	140	39	3,622	699	19
1957	889	302	34	620	139	22	3,460	497	14
1958	1,130	137	12	392	116	30	1,175	262	22
1959	1,132	266	24	284	72	25	915	419	46
1960	1,081	804	74	181	106	59	1,533	835	55
1961	907	755	83	286	180	63	2,849	532	19
1962	898	587	65	172	40	23	2,395	459	19
1963	607	309	51	196	122	62	1,036	359	35
1964	456	354	78	242	141	58	1,716	230	13
1965	781	397	51	808	97	12	1,416	227	16
1966	589	344	58	684	287	42	2,521	476	19
1967	987	320	32	1,932	254	13	3,087	420	14
1968	446	214	48	179	35	20	934	236	25
1969	906	453	50	508	186	37	1,002	287	29
1970	*	*	*	704	278	40	2,060	616	30
1971	*	*	*	1,309	446	34	2,450	718	29
1972	621	349	56	423	158	37	785	240	31
1973	*	*	*	376	137	36	1,213	464	38
1974	1,065	816	77	635	377	59	1,028	567	55
1975	*	*	*	559	305	55	3,990	1,077	27
1976	*	*	*	1,263	373	30	3,081	562	18
1977	944	414	44	185	37	20	2,998	396	13
1978	*	*	*	1,045	236	23	3,132	620	20
1979	1,219	695	57	1,265	460	36	2,460	701	29
1980	1,207	559	46	594	171	29	2,994	515	17
1981	960	350	37	212	18	9	1,170	204	17
1982	638	377	59	226	41	18	1,769	337	19

* No fyke netting done.

TABLE 2. Fingerling densities, angler harvest rates (all sizes), and mean annual growth increments for walleyes in Escanaba Lake, 1956-82.

Year	Walleye Fingerling Density (no./acre)	Angler Harvest Rates (no./angler-hour)	Mean Annual Growth Increments (inches) Ages III-IV	Ages IV-V
1956	-	0.21	-	-
1957	-	0.15	-	-
1958	15	0.04	1.9	1.8
1959	89	0.05	1.6	2.1
1960	0	0.11	0.1	2.3
1961	2.5	0.19	1.7	0.9
1962	50	0.11	1.9	1.0
1963	45	0.07	2.5	2.8
1964	108	0.14	0.6	-
1965	36	0.14	1.8	3.5
1966	76	0.20	1.3	1.8
1967	30	0.23	1.6	1.6
1968	29	0.10	2.3	1.5
1969	65	0.09	-	-
1970	34	0.15	-	-
1971	10	0.16	-	-
1972	5	0.07	-	-
1973	83	0.09	-	-
1974	51	0.10	-	-
1975	7	0.25	-	-
1976	8	0.23	-	-
1977	60	0.17	-	-
1978	15	0.19	-	-
1979	23	0.21	1.6	1.0
1980	3.5	0.22	1.9	1.8
1981	56	0.12	2.2	2.2
1982	21	0.15	-	-

TABLE 3. Relationship between angling and fyke net PSD values and various parameters for walleyes in Escanaba Lake, 1956-82.

	r	df	P
Fyke Net PSD vs.			
Fingerling density			
2 years previous	-0.239	15	>0.05
3 years previous	-0.453	14	>0.05
Annual walleye growth increment (inches)			
Ages III-IV	-0.238	11	>0.05
Ages IV-V	0.184	11	>0.05
Walleye catch/angler-hour	0.171	19	>0.05
Angling PSD (May) vs.			
Fingerling density			
2 years previous	0.199	22	>0.05
3 years previous	-0.494*	21	>0.05
Annual walleye growth increment (inches)			
Ages III-IV	-0.443	13	>0.05
Ages IV-V	-0.085	12	>0.05
Walleye catch/angler-hour	-0.035	25	>0.05
Angling PSD (open water period) vs.			
Fingerling density			
2 years previous	-0.244	21	>0.05
3 years previous	-0.325	20	>0.05
Annual walleye growth increment (inches)			
Ages III-IV	-0.076	13	>0.05
Ages IV-V	0.196	12	>0.05
Walleye catch/angler-hour	-0.484*	25	>0.05

*P = < 0.05

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