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**Trends in body size across an environmental gradient: a differential response in scavenging and non-scavenging demersal deep-sea fish**

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Body size trends across environmental gradients are widely reported but poorly understood. Here we investigate contrasting relationships between size (body mass) and depth in the scavenging and predatory demersal ichthyofauna (800-4800 m) of the NE Atlantic. The mean size of scavenging fish, identified as those regularly attracted to baited cameras, increased significantly with depth, whilst in non-scavengers there was a significant decline in size. The increase in scavenger size is a consequence of both intra and inter-specific effects. The observation of opposing relationships, in different functional groups, across the same environmental gradient indicates ecological rather than physiological causes. Simple energetic models indicate that the

dissimilarity can be explained by different patterns of food distribution. While food availability declines with depth for both groups, the food is likely to be in large, randomly distributed packages for scavengers and as smaller but more evenly distributed items for predators. Larger size in scavengers permits higher swimming speeds, greater endurance as a consequence of larger energy reserves, and lower mass specific metabolic rate, factors that are critical to survival on sporadic food items.

**Keywords: Northeast Atlantic, deep water, fishes, body size, scavengers, predators**

## 1. INTRODUCTION

The size to which an organism grows relates to all aspects of its biology, and determining what controls body size is a fundamental question in ecology (Atkinson & Sibly 1997). Distinct trends in body size over environmental gradients have been demonstrated in many taxa (*e.g.* Bergmann's rule in which endotherm size increases at higher latitudes), but understanding the factors controlling these patterns continues to tax ecologists (*e.g.* Thiele 1975; Peters 1983; Schmidt-Nielson 1984; Atkinson & Sibly 1997; Rex & Etter 1998). Various hypotheses have been proposed to explain body size patterns including both physiological (*e.g.* temperature, oxygen uptake: Pauly 1997; Chapelle & Peck 1999) and ecological (*e.g.* food supply: Thiele 1975) mechanisms. However the presence of conflicting size patterns in related taxa (*e.g.* Ashton & Feldman 2003; Rex & Etter 1998) illustrates the complexity of the problem and demonstrates that no single factor can account for all the observed patterns. A pragmatic approach suggests that while physiological responses to physical variables, such as temperature and oxygen, may limit body size for a given taxa, ecological factors will operate within these physiological constraints.

Within the deep marine environment, patterns of changing animal size with depth have been demonstrated in invertebrates (Thiel 1975; Haedrich & Rowe 1977; Rex & Etter 1998; Olabarria & Thurston 2003) and fish (Polloni *et al.* 1979; Macpherson & Duarte 1991). Early studies of the demersal deep-sea ichthyofauna indicated a general pattern of increased size with depth (Polloni *et al.* 1979), which became known as Heincke's Law (following Heincke's (1913) description of the size of plaice in the North Sea). However subsequent work demonstrated that the phenomenon was not ubiquitous (Snelgrove & Haedrich 1985), may be an artefact of sampling (Merrett

*et al.* 1991b), and in some regions a decline in size with depth has been reported (Stefanescu *et al.* 1992).

Since increased depth is accompanied by changes in hydrostatic pressure, light, temperature and food availability (Gage & Tyler 1991) it may be difficult to determine which variable(s) influence size. The observed trends of both increased and decreased size with depth have been associated with the need to maintain a viable population size in the face of reduced overall energy availability (Thiele 1975; Gage 1978), mass-specific changes in metabolic rate (Rex & Etter 1998) and changes in the relative importance of mobility (Haedrich & Rowe 1977). As the importance of each of these factors depends upon the behaviour and ecology of the species involved, it is not surprising that a clear and consistent pattern has not, so far, emerged.

To date, studies of demersal fish have focussed on patterns in the whole community or individual species, and have not examined trends within functional groups. Here we examine trawl and camera data on demersal fish, over a very large depth range (800-4800 m), from the Porcupine Seabight and Abyssal Plain (NE Atlantic) to examine the relationship between size and depth and consider how it differs between functional groups. Simple energetic models are developed to examine differences in the patterns of body size with depth in scavengers and predators and to consider the consequences of the reduction in food supply with increased depth (Lampitt *et al.* 1986).

## 2. MATERIALS AND METHODS

Between September 2000 and October 2002 five cruises were undertaken on RRS *Discovery* to investigate the ichthyofauna of the Porcupine Seabight (PSB) and Porcupine Abyssal Plain (PAP), SW of Ireland (see Rice *et al.* (1991, 1994) for details of the study sites). Three cruises were undertaken in the late summer/autumn (250, 255, 262) period and two during spring (252, 266). An additional cruise was undertaken on RRS *Challenger* in August 1997.

During each cruise the demersal fauna was sampled using a 45-foot (13.7 m) semi-balloon otter trawl (OTSB). The OTSB is shot on twin warps with 120 kg otter boards and transferred to a single warp once the doors have spread (Merrett & Marshall 1981). Haul duration varied with depth, but was typically 30 min (bottom contact) at the shallowest stations increasing to 3 hr on the abyssal plain. The trawl was towed at a speed of 2.25-3 knots. Swept area was calculated (during RRS *Discovery* cruises only) from the nominal wing-spread of the trawl (8.6 m) and the distance of bottom contact.

The catch was sorted immediately. Fish were identified using published texts (*e.g.* Whitehead *et al.* (1984)), measured, weighed and sexed. Body mass was measured to the nearest gram using a Pols motion compensated balance (accurate to 5 g). In certain cases (*e.g.* damage) fish mass was not recorded, and was estimated from significant length-mass regressions calculated from specimens of the same species. Since length measurements vary between species (following ichthyological convention) body mass was used as an indication of size and the  $\log_{10}$  of body mass of individual fish was used in subsequent analysis.

Species were classified as scavengers if they were attracted to baited camera deployments in the PSB or on the PAP (Collins *et al.* 1999; Priede *et al.* 1994; unpublished data collected during cruises). Bathymetric trends were examined in fish captured at 10 or more stations and with the total number caught exceeding 100. For species analyses only stations that included 3 or more individuals from a species were included. Statistical analyses were undertaken using MINITAB (Release 13). For statistical analyses log<sub>10</sub> transformations were made to the biomass and abundance data.

Simple energetic models were developed to explore the potential role of food distribution and abundance in influencing different patterns in body size seen in scavenging and non-scavenging fish.

### **3. RESULTS**

#### **(a) Analysis of Trawl Data**

Sixty-one trawl stations were undertaken in the PSB and at PAP, which caught 8856 specimens of demersal fish, belonging to 76 species and 29 families. The dominant families were the Macrouridae (13 species; 3246 individuals), Alepocephalidae (16; 297) and Synphobranchidae (2; 3173) and the ten most abundant species are listed in Table 1. The principal scavenging species (identified from previous (Priede *et al.* 1994; Collins *et al.* 1999) and concurrent baited camera studies at the PSB and PAP site were the eels, *Synphobranchus kaupi* and *Histiobranchus bathybius*; the morid, *Antimora rostrata*; the ophidiid, *Spectrunculus grandis*; the grenadier

*Coryphaenoides armatus*; the Portuguese shark *Centroscymnus coelolepis* and the hagfish *Myxine ios*.

Abundance of both scavenging and non-scavenging fish declined significantly with depth (Figure 1a), and there was no difference in the slopes (ANCOVA:  $F=1.53$ ,  $p=0.129$ ) or elevations (ANCOVA:  $F=1.98$ ,  $p=0.163$ ) of the regression lines. The high abundance value of scavengers came from a trawl at 1200 m, which caught 1086 specimens of the eel *S. kaupi*. In non-scavengers biomass declined with depth ( $F=141.23$ ;  $p<0.001$ ), while in scavengers there was a slight, but not significant, increase with depth ( $F=19.30$ ,  $p=0.106$ ; Figure 1b). The difference between scavenger and non-scavenger biomass at each station ( $\log_{10}$  scavenger–  $\log_{10}$  non-scavenger) increased significantly with depth ( $F=66.91$ ,  $p<0.001$ ). The peak in non-scavenger biomass seen in a trawl at 1541 m included over 150 specimens of the roundnose grenadier (*Coryphaenoides rupestris*).

The size of scavenging fish increased significantly with increased depth, whilst the size of non-scavenging fish showed a slight, but significant, decline with increased depth (Figure 1c; Table 1) and the slopes of the regressions differed significantly (ANCOVA:  $F=159.01$ ;  $p<0.001$ ). With increased depth there was a significant increase in both minimum and maximum size of scavenging fish (Table 1).

Patterns of size, biomass and abundance were examined in the three dominant species of scavenger (*C. armatus*; *A. rostrata*; *S. kaupi*) (Figure 2). In each species there was a significant increase in size with depth, which can be quantified by the slope of the relationship between the  $\log_{10}$  body mass and depth (Table 1). Biomass in each



species was maximal towards the deeper end of the depth range, where the larger fish occurred, with abundance higher at the shallower end of the range in both *C. armatus* and *S. kaupi*.

Relationships between size and depth were investigated in the ten most abundant fish species (including the three dominant scavengers; Table 1; Figure 3). Among the non-scavenging species, a significant increase in size with depth was detected in *Coryphaenoides guntheri* and *Bathypterois dubius*, but the increase in size with depth (slope) was considerably lower than in scavenging species. There was a significant decline in size with depth in *Coryphaenoides leptolepis*, but no relationship between size and depth in the other species.

### **(b) Model Development and Predictions**

Non-scavengers: First we assume that, at a given depth, food is evenly distributed across the sea-floor at energy density  $e$ ; that a predator travels at speed  $v$ , can detect food within a distance  $d$ , and so sweeps out area of  $2dv$ . In so doing it uses up energy at its standard metabolic rate  $R$  plus an increment due to the added energetic costs associated with foraging  $S$ . Hence, the energetic requirement for a positive energy balance is such that

$$2dve > R + S \quad (1)$$

Which can be rearranged to give

$$e > \frac{R + S}{2dv} \quad (2)$$

We must now consider how the right side of this equation is affected by the mass of the non-scavenger. Following Ruxton & Houston (2004) we assume that the added cost of foraging is a constant multiple (likely to be around 2) of the standard metabolic rate  $R$ . Standard metabolism will increase with mass to a power of around 0.75. Since detection distance is likely to be determined principally by the physical properties of the water, it is reasonable to consider that maximum food detection distance is independent of the mass of the fish. The search speed of the fish is likely to increase with mass, but will not do so as rapidly as  $R$ ; Ruxton & Houston (2004) suggest that it might scale as mass to the power 0.17. Taken together this indicates that the right side of eqn. (2) increases with fish mass (since the numerator increases more rapidly with increasing mass than the denominator). Hence only fish below some maximum size can achieve a positive energy balance. Further, it is easy to see that, as food density ( $e$ ) declines, so does this maximum size. Hence, we predict that the maximum size of non-scavenging fish should decline with increasing depth.

Scavengers: If we assume that, having discovered a food source, the scavenger is able to completely replenish its energy stores, giving it a supply of energy  $E$ . It then travels at speed  $v$  across the sea-bed, looking for another meal. During this time, it uses energy from its store to fuel both its standard metabolism  $R$  and the added cost of foraging  $S$ . Assuming that food items are randomly scattered over the sea-bed at density  $\rho$ , and can be detected if the fish passes within distance  $d$  of them, by simple geometric reasoning (see *e.g.* Gerritsen & Strickler (1977)), the probability of finding another meal before the energy reserves from the last meal are exhausted is given by:

$$1 - \exp\left(\frac{2dv\rho E}{R+S}\right) \quad (3)$$

If  $\rho$  declines with increasing depth, then to keep this probability constant, the term

$$\left(\frac{2dvE}{R+S}\right), \quad (4)$$

must increase sufficiently to compensate. From our arguments for non-scavengers we expect the denominator of (4) to increase with mass to a power of around 0.75 (but certainly less than one). However, it would be reasonable to assume that energy reserves occupy a constant fraction of a fish's body and so increase with mass to the power one (in fact there is empirical evidence for a power greater than one (Stein & Pearcy 1982)). Search speed is likely to increase with mass, and detection distance is likely to be relatively insensitive to mass. Taken together we expect that (4) will increase in magnitude for fish of increasing mass. Hence, to maintain a fixed probability of surviving from one meal to the next, in the face of declining food density (declining  $\rho$ ), demands fish of increasing mass.

Thus, for scavengers we predict that for any energy density, there will be a minimum fish size below which survival from one meal to the next becomes improbable. Further we expect this minimum size to increase with declining food density, and so body mass of scavengers would be expected to increase with increasing depth. As a result, body size in scavengers and non-scavengers is controlled in opposite ways. Scavengers must maintain a minimum body size in order to maintain endurance, while the maximum potential size of predators (non-scavengers) is progressively constrained.

#### 4. DISCUSSION

In contrast to terrestrial and shallow marine habitats, environmental gradients in the deep-sea are temporally very stable (Gage & Tyler 1991), which potentially makes it easier to detect relationships with body size. The data presented here indicates clear differences in the size-depth trends between scavenging and non-scavenging demersal fish. However, before considering explanations for the different trends it is important to understand the limitations of the data. Merrett *et al.* (1991a, b) demonstrated that the large, active fish of the upper slope of the PSB were able to avoid small trawls, leading to a distinct bias in the data. This study, which used the same gear, is almost certainly subject to the same bias, however we argue that these fish are, with the exception of the shark *Centroscymnus coelolepis*, not scavengers. The failure to catch the larger fish of the upper slope would therefore result in an under-estimate of the decline in size with depth of the non-scavengers. *Centroscymnus coelolepis* is a large scavenger, found at 685-1270 m (Merrett *et al.* 1991a), which does not fit with the general trend of increased scavenger size with depth presented here. For reasons that are not yet clear, controls on the depth distribution of the Classes Chondrichthyes and Osteichthyes appear to differ, but given the wide anatomical, behavioural and physiological differences between bony and cartilaginous fishes the differences in distribution are perhaps not surprising. A further potential bias is that size frequency distributions may simply reflect recent recruitment history (see McClain & Rex 2001), however there was a significant increase in the maximum size of scavengers, and within scavenging species there are clear patterns of size increase with depth, indicating recruitment occurs at the shallow end of the depth distribution.

Although a range of physical parameters (light, temperature, pressure) vary between 800 and 4800 m, the fact that opposing size-depth patterns are seen in different functional groups in the same habitat clearly indicates an ecological rather than purely physiological explanation, and this is supported by the theoretical predictions. The key difference between scavengers and non-scavengers is the distribution of the available food, which we assume to be uniformly distributed for non-scavengers (Ruhl & Smith 2004) but aggregated into large, sparsely-distributed packages for scavengers (Smith & Baco 2003). The theoretical predictions assume a decline in food availability with depth for both functional groups. Lampitt *et al.* (1986) showed a logarithmic decline in megabenthos biomass from 800-4100 m in the PSB, which is a proxy for predator food availability. The distribution of carrion is not so well described (Jones *et al.* 1998; Stockton & Delacca 1982; Smith & Baco 2003), but is likely to decline with distance from shore and hence usually with depth. Consequently, the relative selective pressures for swimming speed, nutrient storage, and metabolic economy will differ greatly between scavengers and non-scavengers, even when these species are closely related (note that the 4 species of *Coryphaenoides* show positive, negative and no relationship with depth; Figure 3). Scavengers are probably able to trade-off a high absolute energy requirement against the ability for faster swimming and greater endurance because of the high food value of carrion. These attributes allow the fish to arrive at carrion before it has been consumed (Haedrich & Rowe 1977), and increase their chances of reaching another meal before starving (Peters 1983). In contrast, predators in such low-food environments must reduce absolute costs to a minimum, and therefore larger body sizes cannot be sustained. Endurance is not so important, as another food item is likely to be found

relatively soon, but as each food item is of lower value they must continually balance energy inputs and outputs.

The data reported here are difficult to compare with other regions, as no other studies have contrasted scavengers and non-scavengers, and no study has combined such extensive trawl sampling (and body mass measurements) with the baited camera data required to discriminate between these functional groups. Without these behavioural data it is difficult to know which functional group a fish belongs to. Not all individuals of the same species have the same behaviour, with ecology varying geographically (*e.g.* the macrourid *Chalinura mediterranea* and shrimp *Acantheephyra eximia* are scavengers in the Mediterranean (Jones *et al.* 2003), but are not attracted to bait in the NE Atlantic) and with ontogeny. Within many scavenging species there is a switch from a generalist diet to scavenging with increased size, and that appears to be the case for the three main scavenging species in the PSB. Small individuals of *Antimora rostrata* and *Coryphaenoides armatus* are not attracted to baited cameras at depths where they are abundant in trawls (Priede *et al.* 1994; Collins *et al.* 1999) and this is supported by the limited diet data (Mauchline & Gordon 1984; Martin & Christiansen 1997). Small *Synaphobranchus kaupi* are attracted to baited cameras (Priede *et al.* 1994), but diet studies do indicate an increase in dependence on scavenging in larger fish (Gordon & Mauchline 1996). This supports the prediction that at a particular food density, there will be a threshold minimum size necessary to support a scavenging lifestyle. Small individuals may not be able to compete with larger conspecifics as scavengers and hence occupy a different niche. The model assumes that the scavenging species are obligate scavengers, and although Britton & Morton (1994) suggested that there are no obligate scavengers in the marine

environment, it has been demonstrated that it is theoretically energetically possible for a mobile fish to be an obligate scavenger (Ruxton & Houston 2004; Ruxton & Bailey in press). However, we can see no evolutionary pressure that would force a fish to give up the ability to take some live prey, suggesting that a predominant scavenger is more likely than an obligate one.

Intra-specific bigger-deeper trends have been identified in this study, and in previous work (*e.g.* Macpherson & Duarte 1991), in both scavenging and non-scavenging species, but the slopes of the relationships between size and depth are greater in scavenging species. It has been argued that the size depth pattern should be described as shallower smaller rather than bigger-deeper (Merrett *et al.* 1991a), however our data indicate that, for scavengers in general and for individual scavenging species, both minimum and maximum size increase with depth, indicating a genuine bigger-deeper trend.

The bathymetric succession of scavenging species is probably a consequence of inter-specific competition, with *Coryphaenoides armatus* unable to compete with the more active *Antimora rostrata* (Collins *et al.* 1999), and with the shallower *Synaphobranchus kaupi* even more active (Bailey *et al.* 2005b). Conversely, with increasing depth, the more active fish are unable to find enough food to support their higher metabolism (Bailey *et al.* 2005b). In a multi-species scavenging assemblage like that in PSB/PAP the larger scavenging fish probably inhabit deeper water to avoid competition with both smaller fish of their own species and large individuals of the “shallower” scavengers. Both of these groups will lack the endurance necessary to survive at greater depth because either their energy stores will be too small, or their

metabolic rates will be too high. This scenario is similar to that seen in seabirds across a productivity gradient, where competition and energetic constraints mean that larger birds forage in productive areas, with smaller birds in the less productive locations (Ballance *et al.* 1997).

Our data are predominantly for teleost fish, and as noted for elasmobranchs the patterns may differ between taxa. Theoretically the advantages of large size will also apply to invertebrate scavengers, and many of the large deep-sea invertebrates are also scavengers (*e.g.* the scavenging amphipod *Eurythenes gryllus* and the lithodid crab *Neolithodes grimaldii*). In the Mediterranean, the decapod shrimp *Acantheephyra eximia* is regularly attracted to bait, with larger individuals found at greater depths (Bailey *et al.* 2005a). Gastropod taxa also show both increases and decreases in size with depth, which may be related to the ecology of the species (Rex & Etter 1998; Olabarria & Thurston 2003).

In this study we have demonstrated the power of comparing different functional groups to generate hypotheses about the factor or factors influencing variation in individual size with depth and how these hypotheses can be investigated with simple mathematical models. The clear differences in body size patterns with depth in the two functional groups demonstrate that, within the physiological boundaries, the ecology of a species can profoundly influence the optimal size of an organism across an environmental gradient. Understanding the patterns of body size across environmental gradients thus requires an understanding of both the ecology and physiological constraints of the species concerned.



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## FIGURE LEGENDS

Figure 1. Relationships between abundance (a), biomass (b) and mean size ( $\log_{10}$  body mass) (c) and depth for scavenging and non-scavenging demersal deep-sea fish in the Porcupine Seabight and Abyssal Plain.

Figure 2. Relationships between abundance (a), biomass (b) and mean size ( $\log_{10}$  body mass) (c) and depth in the three dominant scavenging species (*Coryphaenoides armatus* (COA), *Synaphobranchus kaupi* (SYK) and *Antimora rostrata* (ANR) in the Porcupine Seabight and Abyssal Plain.

Figure 3. Body mass-depth relationships for the ten most abundant species of demersal fish caught in the Porcupine Seabight and Abyssal Plain (heavy line = scavengers; broken line = non-scavengers); see Table 1 for species codes.

**Short title: Trends in body size across an environmental gradient**

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Table 1. Regression parameters for relationships between size (dependent) and depth (predictor) for scavenging and non-scavenging fish and the ten most abundant species caught in the Porcupine Seabight. Regression data are also presented for the minimum and maximum size of scavengers. Significant regressions in bold.

Species	Intercept	Slope	N (hauls)	n (fish)	F	p	r <sup>2</sup>
<b>All fish</b>	<b>1.386</b>	<b><math>2.65 \times 10^{-4}</math></b>	<b>61</b>	<b>8845</b>	<b>69.03</b>	<b>&lt;0.001</b>	<b>0.54</b>
Scavengers (mean)	<b>0.622</b>	<b><math>5.86 \times 10^{-4}</math></b>	<b>58</b>	<b>4533</b>	<b>165.37</b>	<b>&lt;0.001</b>	<b>0.75</b>
Scavengers (max)	<b>1.364</b>	<b><math>5.45 \times 10^{-4}</math></b>	<b>58</b>	<b>4533</b>	<b>46.64</b>	<b>&lt;0.001</b>	<b>0.46</b>
Scavengers (min)	<b>-0.232</b>	<b><math>5.80 \times 10^{-4}</math></b>	<b>58</b>	<b>4533</b>	<b>106.90</b>	<b>&lt;0.001</b>	<b>0.66</b>
<i>Antimora rostrata</i> (ANR)	<b>-1.567</b>	<b><math>1.88 \times 10^{-3}</math></b>	<b>24</b>	<b>304</b>	<b>481.73</b>	<b>&lt;0.001</b>	<b>0.96</b>
<i>Coryphaenoides armatus</i> (COA)	<b>1.328</b>	<b><math>4.04 \times 10^{-4}</math></b>	<b>27</b>	<b>248</b>	<b>248.3</b>	<b>&lt;0.001</b>	<b>0.88</b>
<i>Synaphobranchus kaupii</i> (SYK)	<b>-0.431</b>	<b><math>1.21 \times 10^{-3}</math></b>	<b>28</b>	<b>3094</b>	<b>78.33</b>	<b>&lt;0.001</b>	<b>0.75</b>
Non-scavengers	<b>2.033</b>	<b><math>-5.64 \times 10^{-5}</math></b>	<b>61</b>	<b>4312</b>	<b>4.42</b>	<b>0.040</b>	<b>0.07</b>
<i>Bathypterois dubius</i> (BPD)	<b>0.869</b>	<b><math>5.23 \times 10^{-4}</math></b>	<b>11</b>	<b>126</b>	<b>5.671</b>	<b>0.041</b>	<b>0.39</b>
<i>Coryphaenoides guntheri</i> (COG)	<b>0.963</b>	<b><math>4.18 \times 10^{-4}</math></b>	<b>24</b>	<b>1165</b>	<b>38.73</b>	<b>&lt;0.001</b>	<b>0.64</b>
<i>Coryphaenoides leptolepis</i> (COL)	<b>2.965</b>	<b><math>-3.56 \times 10^{-4}</math></b>	<b>11</b>	<b>190</b>	<b>9.070</b>	<b>0.015</b>	<b>0.50</b>
<i>Coryphaenoides rupestris</i> (COR)	2.049	$3.20 \times 10^{-4}$	19	439	1.045	0.321	0.06
<i>Halosaurusopsis machrochir</i> (HAM)	2.176	$9.01 \times 10^{-6}$	16	229	0.024	0.878	0.00
<i>Lepidion eques</i> (LEE)	1.576	$7.56 \times 10^{-5}$	17	764	0.052	0.822	0.00
<i>Nezumia aequalis</i> (NEA)	1.192	$3.50 \times 10^{-4}$	11	261	0.884	0.372	0.09

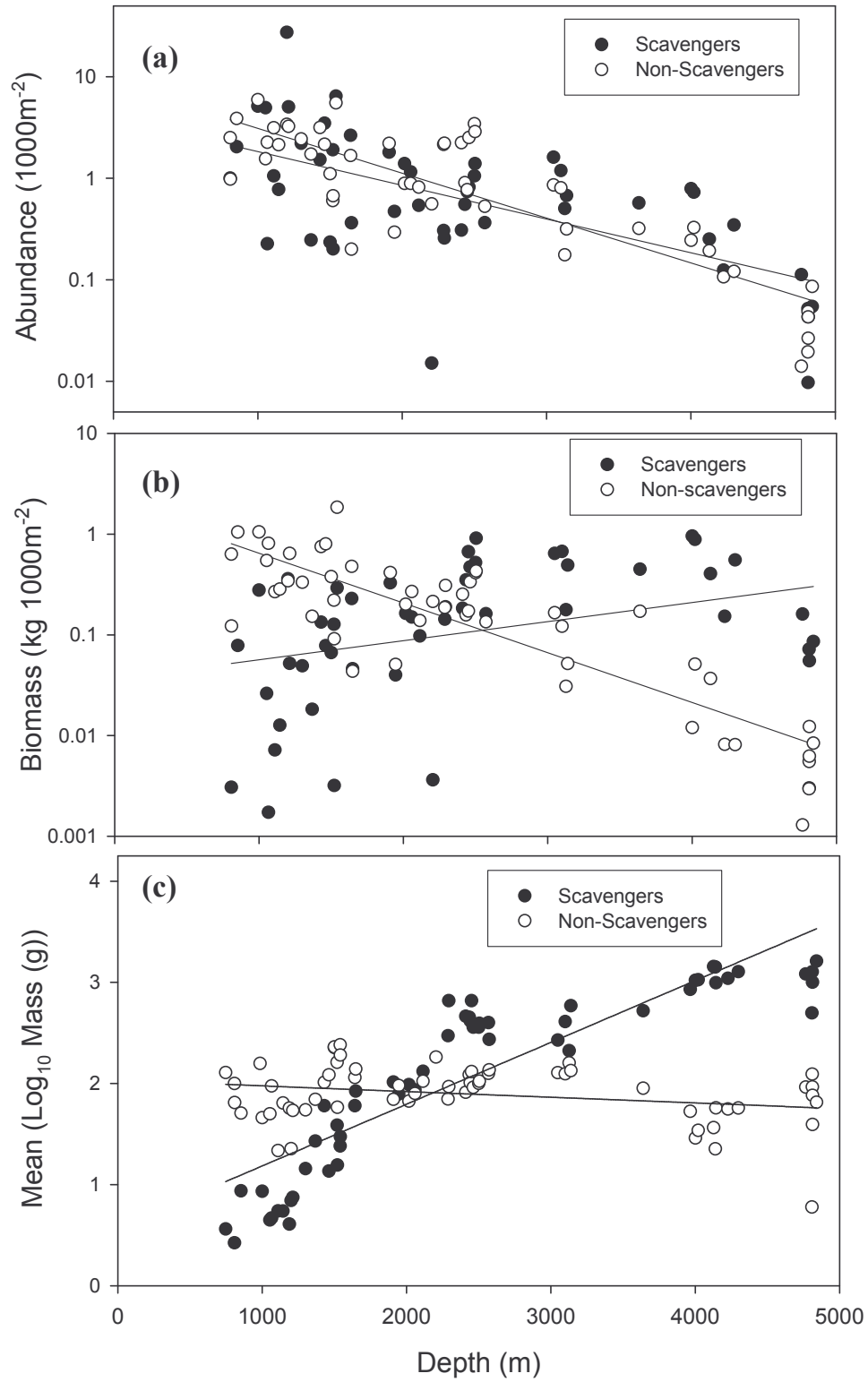


Figure 1



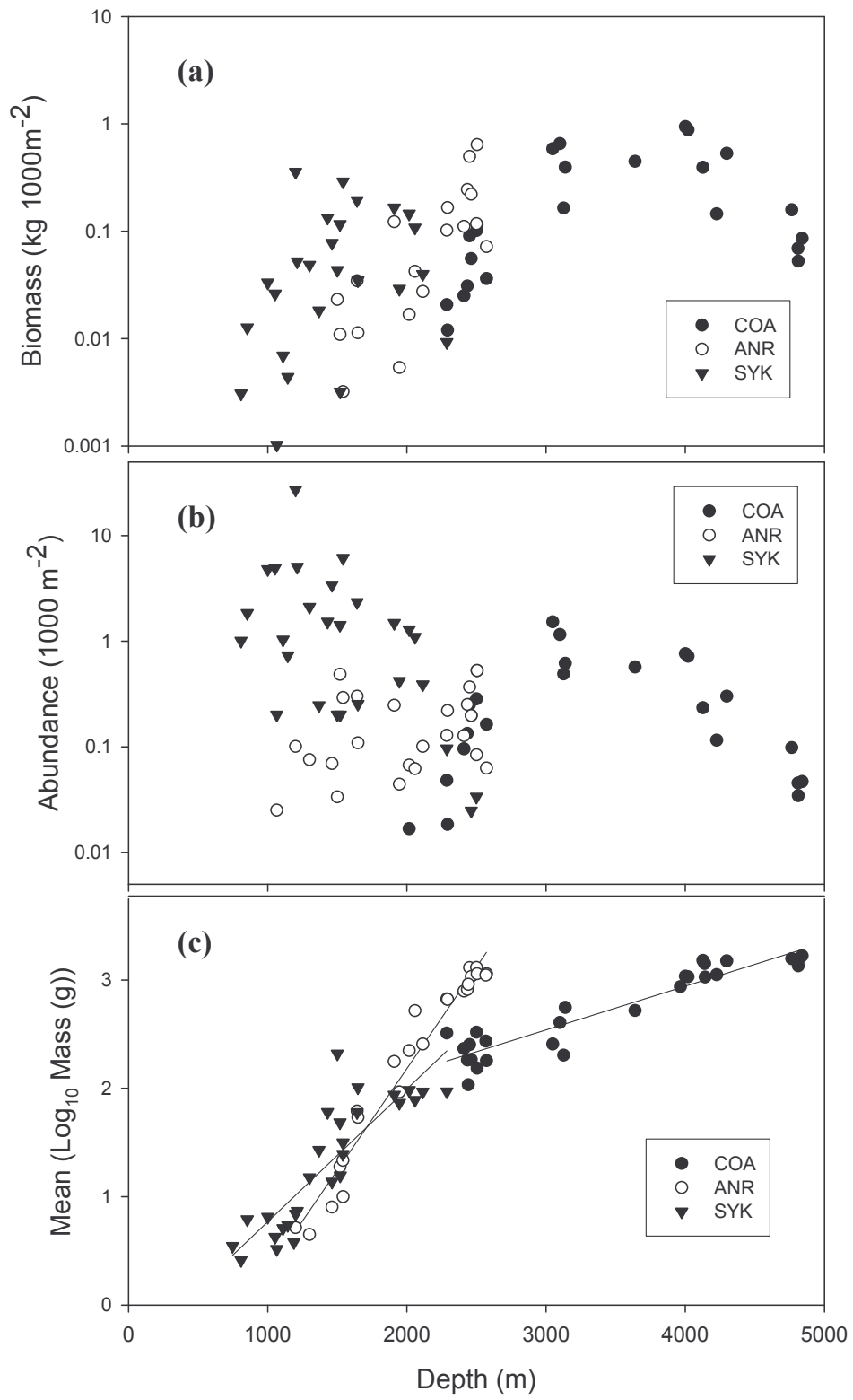


Figure 2

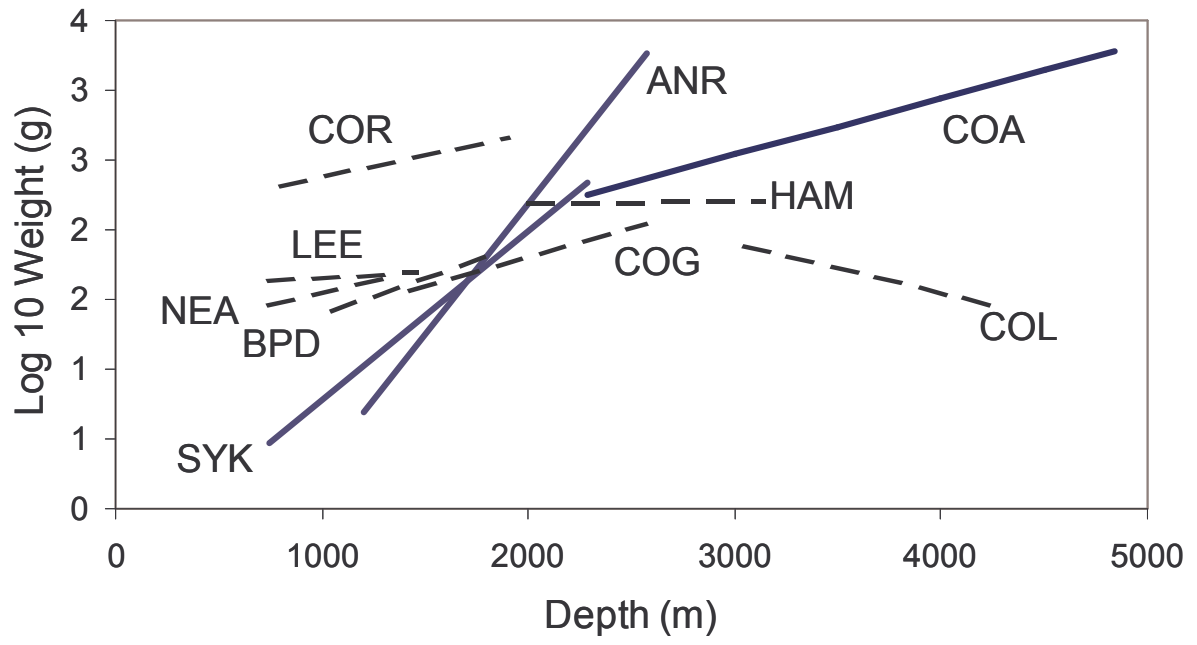


Figure 3.

Potentially for online appendix.

Appendix 1. List of trawl stations in the Porcupine Seabight and Porcupine Abyssal Plain from which fish were sampled.

Cruise	Station	Date	Latitude	Longitude	Depth	Fish Count
Challenger 134	4	8/9/1997	50° 10' N	14° 35' W	3965-3965	106
Challenger 134	6	8/9/1997	49° 50' N	14° 18' W	4143-4143	43
Challenger 134	8	8/11/1997	50° 2' N	12° 48.5' W	2441-2441	220
Challenger 134	11	8/12/1997	50° 2.1' N	13° 2.9' W	2567-2567	85
Challenger 134	15	8/14/1997	49° 33' N	11° 36' W	747-747	111
Challenger 134	16	8/14/1997	49° 38' N	11° 49' W	985-985	69
Challenger 134	17	8/14/1997	49° 37.5' N	12° 2.5' W	1188-1188	79
Challenger 134	21	8/16/1997	49° 32.5' N	12° 48.5' W	1540-1540	260
Challenger 134	24	8/16/1997	49° 57.8' N	14° 28.9' W	4139-4139	121
Discovery 250	13906	9/18/2000	50° 11.9' N	14° 39.6' W	3986-4016	152
Discovery 250	13910	9/21/2000	49° 50.6' N	12° 56.8' W	2456-2467	135
Discovery 250	13914	9/22/2000	49° 54.8' N	13° 34.3' W	2981-3115	141
Discovery 250	13916	9/24/2000	49° 36.3' N	13° 32.2' W	2023-2093	99
Discovery 250	13919	9/25/2000	51 8.9' N	12° 3.9' W	1537-1545	532
Discovery 250	13922	10/1/2000	50° 53.9' N	11° 58.4' W	1885-1933	162
Discovery 250	13925	10/7/2000	48 53.5' N	16° 45.9' W	4835-4845	18
Discovery 252	13928	4/15/2001	49° 30' N	12° 55.2' W	1500-1500	80
Discovery 252	13932	4/16/2001	49° 51.2' N	12° 52.5' W	2398-2470	87
Discovery 252	13935	4/17/2001	49° 49.6' N	13° 8.5' W	2400-2500	90
Discovery 252	13942	4/19/2001	50° 3.9' N	14° 40' W	4011-4029	126
Discovery 252	13945	4/20/2001	50° 12.0' N	14° 10.1' W	3560-3718	78
Discovery 252	13951	4/22/2001	49° 49.9' N	12° 10.8' W	1631-1653	258
Discovery 252	13952	4/23/2001	49° 43' N	11° 46.1' W	1053-1077	99
Discovery 252	13960	4/25/2001	49° 54.1' N	12° 20.9' W	2274-2300	153
Discovery 252	13963	4/27/2001	49° 49' N	11° 51.8' W	1175-1250	330
Discovery 252	13964	4/27/2001	49° 33' N	11° 33.7' W	772-845	39
Discovery 255	14132	8/16/2001	49° 17' N	12° 22.2' W	1131-1156	202
Discovery 255	14137	8/19/2001	49° 36.9' N	14° 4.6' W	4108-4146	53
Discovery 255	14141	8/20/2001	49° 59.3' N	12° 53.4' W	2494-2514	227
Discovery 255	14143	8/21/2001	49° 45.7' N	12° 53.5' W	2275-2308	134
Discovery 255	14146	8/22/2001	49° 35.2' N	12° 52.2' W	1625-1672	31
Discovery 255	14147	8/23/2001	49° 31.9' N	12° 50.7' W	1515-1523	150
Discovery 255	14151	8/24/2001	49° 41.9' N	13° 11.8' W	1915-1976	104
Discovery 255	14156	8/27/2001	49° 52.1' N	13° 34.1' W	3089-3186	69
Discovery 255	14158	8/28/2001	49° 32.2' N	14° 23.3' W	4286-4311	31
Discovery 255	14163	8/29/2001	49° 26.7' N	12° 41.5' W	1340-1397	72
Discovery 255	14164	8/30/2001	49° 44.3' N	11° 43.1' W	1022-1084	259
Discovery 255	14165	8/31/2001	51° 26.2' N	12° 26.0' W	1414-1509	243
Discovery 255	14168	9/1/2001	51° 27.6' N	12° 29.1' W	1498-1544	25
Discovery 255	14170	9/1/2001	51° 36.4' N	11° 53.3' W	775-842	161
Discovery 260	14302	3/11/2002	49° 57.8' N	12° 42.8' W	2365-2456	240
Discovery 260	14309	3/16/2002	49° 43.2' N	13° 10.4' W	2011-2218	108

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Discovery 260	14315	3/18/2002	49° 56.6' N	13° 30.9' W	3030-3168	119
Discovery 260	14317	3/19/2002	49° 39.4' N	14° 15.5' W	4190-4263	26
Discovery 260	14319	3/20/2002	49° 52.4' N	13° 01' W	2555-2590	71
Discovery 260	14322	3/21/2002	49° 49.5' N	12° 32.3' W	2177-2230	38
Discovery 260	14323	3/21/2002	49° 36.6' N	12° 11.8' W	1419-1440	233
Discovery 260	14325	3/22/2002	49° 40.3' N	11° 55.7' W	1100-1119	167
Discovery 266	15048	9/30/2002	51° 15.3' N	11° 54.8' W	1200-1200	1226
Discovery 266	15051	10/1/2002	51° 26.9' N	11° 54.3' W	1000-1000	330
Discovery 266	15052	10/1/2002	50° 4.8' N	12° 45.7' W	2500-2500	268
Discovery 266	15054#22	10/9/2002	48° 43.1' N	16° 33.8' W	4809-4814	10
Discovery 266	15054#24	10/10/2002	48° 40' N	16° 42.5' W	4809-4814	4
Discovery 266	15054#25	10/11/2002	48° 55' N	16° 5.7' W	4809-4812	6
Discovery 266	15054#6	10/3/2002	48° 57.4' N	16° 17.7' W	4810-4810	11
Discovery 266	15054#8	10/4/2002	48° 53.8' N	16° 10.8' W	4808-4808	4
Discovery 266	15055#2	10/12/2002	49° 25.8' N	15° 25.5' W	4749-4780	9
Discovery 266	15058	10/14/2002	49° 40.6' N	13° 1.6' W	1992-2040	136
Discovery 266	15062	10/15/2002	49° 48.9' N	13° 42.9' W	3071-3181	54
Discovery 266	15063	10/18/2002	49° 40' N	11° 30.7' W	785-920	177
Discovery 266	15066	10/19/2002	49° 50.4' N	12° 5.1' W	1240-1360	185