Body Size Distribution and Frequency of Anthropogenic Injuries of Bluntnose Sixgill Sharks, *Hexanchus griseus*, at Flora Islets, British Columbia

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The Bluntnose Sixgill Shark (*Hexanchus griseus*) is a widely distributed demersal species whose population biology is poorly understood. Although *H. griseus* is normally found in deep continental slope waters, individuals from a population in the Strait of Georgia, British Columbia, make unexpected diurnal movements onto a shallow reef (Flora Islets) between June and August. This shallow water activity allowed *in situ* length measurements to be made on 35 free-swimming Bluntnose Sixgill Sharks using stereo videography. The measured sharks were all large juveniles and sub-adults, although smaller juveniles and pregnant females are known to occur in deeper adjacent waters. The restricted size distribution at Flora Islets may arise because small juveniles avoid contact with larger conspecifics and mating takes place offshore. All measured sharks were individually identified by unique scar patterns. In 13 of 35 sharks these scars were consistent with injuries expected from hooking and entanglement by commercial fishing gear.

Key Words: Sixgill Sharks, *Hexanchus griseus*, length-frequency distribution, anthropogenic injury, British Columbia.

The Bluntnose Sixgill Shark (*Hexanchus griseus*) is a demersal species found along the continental slopes of the Pacific, Atlantic, and Indian Oceans (Compagno 1984). *Hexanchus griseus* is one of the most widely distributed (Compagno 1984) and largest of fishes (length to at least 4.8 m; Castro 1983), and the highest trophic level predator throughout its range (Ebert 1994; Froese and Pauly 2005*), feeding on a variety of large prey items (Hart 1973; Compagno 1984; Ebert 1986, 1994). In British Columbia the Bluntnose Sixgill Shark occurs in the Strait of Georgia and the deep inlets of the mainland coast and the west coast of Vancouver Island (Hart 1973). There is little information on the population biology of *H. griseus*, despite its wide distribution, because it is not usually exploited commercially and scientific collecting has been limited due to the potential for adverse effects on local populations (Ebert 1986, 1994; Clark and Kristof 1990; Carey and Clark 1995). Although *H. griseus* is normally a deep water species, in the vicinity of Flora Islets in the Strait of Georgia, British Columbia, a number of Bluntnose Sixgill Sharks make diurnal movements into shallow water (20-40 m) between June and August. This activity provides a unique opportunity to collect quantitative behavioural and population data for *H. griseus* using simple and non-invasive underwater camera systems (Dunbrack and Zielinski 2003). In this paper a stereo video measurement technique is used to derive the body length-frequency relationship for Bluntnose Sixgill Sharks at Flora Islets.

Study Area

The study site is immediately adjacent to Flora Islets, a chain of three small islets southeast of Hornby Island in the Strait of Georgia (49º30.9'N, 124º34.5'W; Dunbrack and Zielinski 2003). The remote cameras used for length measurements were attached to the vertical face of a submerged rocky reef which parallels Flora Islets to the southwest 50 to 100 m offshore. Water depth at the base of the wall increases in a southeasterly direction from 30 m to over 200 m.

Methods

Length measurements were derived from analysis of paired images taken with two low light, black and white video cameras in waterproof housings. The cameras were mounted along a vertical pipe tied into the face of the reef wall with one camera 2.5 m above the other and both cameras facing down to the base of the wall which was 5 m below the lower camera and at a depth of 35 m. Individual cables from each camera ran to a surface float and terminated in waterproof connectors that could be plugged into leads on a surface vessel for recording. Stereo video length measurements of a 213 cm pipe, replicated in various parts of the cameras' visual fields, had a mean error of 2% (maximum error 4.9%). A detailed description of the stereo measurement system is given in Dunbrack (*in press*).

Individual sharks could be identified by distinctive lateral scar patterns; however, as a shark swam below the cameras, only its right or left side was visible. To ensure that individual sharks were included only once in the analysis, length measurements were restricted to sharks displaying their right side scar patterns, that is sharks moving from left to right, inbound from deep water (a more frequently observed pattern than right to left, outbound movements). All sharks that were completely visible from both cameras, and could be individually identified, were measured. There was no body size bias in the ability to identify individuals. This was primarily dependent on the ambient light level, which was generally low within the two hours following sunrise or preceding sunset, and varied substantially in response to fluctuations in the density of particulate matter in the upper water layers.

Results

A total of 50 length measurements of 35 individual sharks were obtained from recordings made between 10 August and 15 September 2001 and between 10 July and 21 July 2002. The total of 50 includes one or two repeat measurements of 13 individuals that were filmed on multiple occasions. The average difference for these repeat measurements ((largest-smallest)/smallest) ×100) was 1.9% (maximum difference 4.7%). The body length-frequency distribution is roughly bell shaped with 80% of measurements falling between 180 cm and 300 cm (Figure 1). Mean, minimum and maximum lengths of the 35 sharks were 240 cm, 135 cm, and 353 cm, respectively. In most cases it was not possible to determine a shark's sex; however, all individuals greater than 280 cm were observed at close range under good illumination and could be sexed based on pelvic fin morphology. All sharks over 280 cm were females (n = 7).

The scars used to identify sharks varied from relatively small light patches to groups of long parallel lines running along the right lateral dorsal surface (Figure 2). The origin of these parallel scars is uncertain but they are consistent with injuries expected from hooking and subsequent entanglement with commercial fishing gear (dogfish longlines or bait lines attached to commercial prawn traps). Scars of this type were seen in 13 of the 35 sharks, a number that probably underestimates injury frequency because observations were confined to the right hand dorsal side; the left side and the jaw region, where divers frequently observe hooking injuries, were not visible in any of the measured sharks.

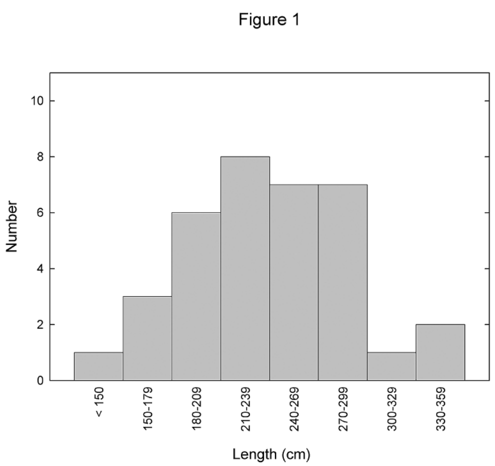

FIGURE 1. Body length-frequency relationship for 35 Bluntnose Sixgill Sharks observed at the Flora Islets reef.

Discussion

Newborn Bluntnose Sixgill Sharks are approximately 70 cm in length; minimum length at maturity is greater than 400 cm for females and greater than 314 cm for males (Ebert 1989). The size range at Flora Islets was 135 cm to 353 cm and all sharks over 280 cm were females, indicating that at Flora Islets all Bluntnose Sixgill Sharks are large juveniles and subadults. Smaller juveniles (75 cm) occur in deeper adjacent waters (Miller and Greenfield 1965) and there is a single record of a pregnant female (>400 cm) from the same area (S. McFarlane, Canada Fisheries and Oceans, Nanaimo, British Columbia, personal communication) The absence of adults and the smallest juveniles from Flora Islets reef is in agreement with data from Barkley Sound on the west coast of Vancouver Island. Here, visual length estimates of 55 *H. griseus* observed in shallow water by divers, ranged from 100 cm to a maximum of 300 cm for males and 360 cm for females (N. McDaniel, Subsea Enterprises, Vancouver, British Columbia, personal communication), whereas 43 immature sharks captured in the same area on deepwater longlines during a 1994 tagging study, varied in length from 86 cm to 400 cm (Canada Fisheries and Oceans, Nanaimo, British Columbia, unpublished report). These data indicate that in Barkley Sound the smallest juveniles probably stay in deep water, and that sexually mature fish are rare.

The apparent absence of the smallest juveniles from shallow water in Barkley Sound and at Flora Islets could result from their use of habitats or foraging behaviors different from those of larger conspecifics, possibly to enhance growth or deter cannibalism (Ebert 1989). The virtual lack of sexually mature adults in deep or shallow water at either site is problematic but could be connected to age-dependent movements whereby birth and juvenile development take place in productive inshore waters but mating occurs elsewhere, probably offshore. Geographic separation of adult and juvenile *H. griseus* has been reported previously (Ebert 1989; Castro et al. 1999) and is common in other shark species (Hoenig and Gruber 1990; Compagno 2001).

Approximately one third of the Bluntnose Sixgill Sharks observed at Flora Islets bore scars consistent with commercial gear entanglement; however, no injuries of this type were observed in the seven sharks greater than 280 cm or in the three smallest sharks (<180 cm). Although the sample size is small, this suggests that the largest sharks may be able to break off hooks or leaders without entanglement, whereas sharks below 280 cm may escape after a period of struggle, but with a probability that decreases as body size decreases. Unfortunately, there are no bycatch data available for *H. griseus* to test this hypothesis.

Body size-frequency distributions can provide information on a range of population-level processes in fishes including growth and mortality rates and size or age-based differences in habitat use (Moyle and Cech 1996). Length-frequency data for commercial species are readily available from catch statistics, and for non-commercial species are generally obtained from targeted collecting. However for large, deep water species, such as *H. griseus*, the collection of length-frequency data can be difficult or unacceptably destructive and the size structure of most large deep water fishes is poorly known (Casey and Taniuchi 1990). Here we have demonstrated that meaningful population data for such species can be obtained using non-invasive remote imaging techniques applied at strategically placed observing stations. Although extension of this technique to other species would require the identification of similar seasonal population aggregations, such seasonal movements are common in fishes. For example, we have recently used remote video imaging to quantify seasonal activity patterns in another little known deep water cartilaginous fish, the chimaerid *Hydrolagus colliei* (unpublished).

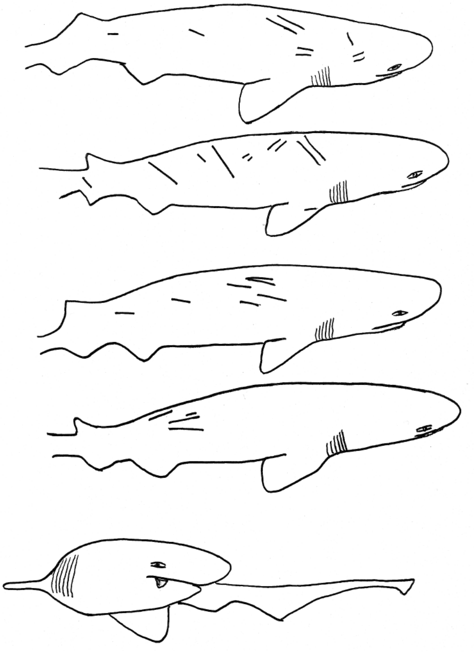

FIGURE 2. *Hexanchus griseus* outlines traced from single video frames. Injury markings are indicated by dark lines (injuries actually appear as lighter markings against a uniformly dark dorsal surface.) The top four sharks were viewed from their right side and show injuries along their lateral dorsal surface. The bottom shark (not measured) has a large indentation in its lower jaw caused by a hook.

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