An evaluation of gray whale (*Eschrichtius robustus*) mortality incidental to fishing operations in British Columbia, Canada[1]

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ABSTRACT

Gray whale (*Eschrichtius robustus*) mortality incidental to commercial fishing operations in British Columbia (BC), Canada was evaluated by two methods: a mailed questionnaire survey of all commercial fishing licence holders in the province; and a review of records of incidental catches, strandings and dead floating animals from published and unpublished sources. Of 5,375 surveys sent out, 848 were returned of which 729 could be used (15.8%). Forty-two incidents with gray whales were reported, including three mortalities. From sources other than the questionnaire for the period up to 1989, 41 records of stranded and dead floating gray whales were obtained, of which four were judged to have been killed incidentally in fishing operations. Twenty-six of these animals had not been examined closely, but extrapolation from the 15 detailed records suggests that 27% of the dead gray whales reported in BC die incidentally in fisheries. Collisions with fishing gear are estimated to occur approximately 20 times per year. Mortality occurs in salmon drift gillnet, salmon seine, longline and trap fisheries. There is also one record of an individual entangled and drowned in a herring net pen, as well as an individual entangled in a herring set gillnet. Estimates of annual mortality are approximately two individuals using data obtained from the questionnaire and 2.4 individuals using stranding data. Biases are present for both sampling methods, but the estimated mortality levels are small relative to population size. Subsequent records ($n = 40$) for the period 1990–95 were also examined for comparison.

KEYWORDS: GRAY WHALE; NORTH PACIFIC; INCIDENTAL CAPTURE; STRANDINGS

INTRODUCTION

Much information is available on the stock size, population dynamics, reproductive parameters and geographic range of the gray whale, *Eschrichtius robustus*, e.g. IWC (2003). In addition, estimates of mortality from all non-natural sources are needed if sustainable catch limits are to be estimated. For gray whales, directed aboriginal subsistence takes are reported, but the levels of indirect mortality from encounters with commercial fishing gear were for a long time largely unknown.

There are three general methods of studying mortality incidental to fisheries: (1) questioning fishermen; (2) having dedicated observers recording kills on fishing vessels; and (3) examining stranded or entangled individuals (Hall and Donovan, 2002). In British Columbia (BC), Canada, dedicated observers are generally not required in domestic fisheries and little work was done on strandings prior to the late1980s. Although several studies of gray whales have been undertaken along the BC coast (e.g. Jones *et al*., 1984; Reeves and Mitchell, 1988; Duffus, 1996; Dunham and Duffus, 2002), none have examined strandings or incidental mortality. In fact, prior to 1987, the only detailed published stranding record was presented in Pike and MacAskie's (1969) comprehensive review of the marine mammals of British Columbia. In Reeves and Mitchell's (1988) review of the status of the gray whale, no mention is made of entanglements in fishing gear in Canadian waters, although entanglements with fishing gear and strandings from elsewhere in their range have been reported by numerous authors (e.g. see Heyning and Dahlheim, In Press). Fisheries-related mortality of other species of cetaceans in Canadian waters has been reported by several authors (see review by Barlow *et al*., 1994). However, from an examination of unpublished references (i.e. Goodman, 1984; Canada, 1985) and from work on strandings (Baird *et al*., 1988; 1991; Stacey *et al*., 1989; Langelier *et al*., 1990; Guenther *et al*., 1995), it is clear that gray whale strandings and incidental catches in BC are more frequent than indicated by the published literature.

This study attempted to estimate the levels of incidental mortality of gray whales in BC using two methods: a mailed questionnaire survey to commercial fishermen; and a review of both published and all available unpublished records of stranded and dead floating gray whales (hereafter these two types of records are referred simply as stranding records). Derivation of estimates using the two different methods also allows examination of the biases involved in using such methods for estimating incidental mortality. Estimates of incidental mortality of gray whales in BC can be combined with such estimates from elsewhere in their range (Heyning and Dahlheim, In Press), for use in better understanding their population dynamics.

METHODS

Questionnaire data, 1989

A single page questionnaire and a pre-paid, pre-addressed return envelope were sent to all commercial fishing licence holders in BC in 1989. A total of 5,375 surveys was mailed to the licensees.

The questionnaire was prefaced with an introductory letter that described the nature of the study. It also noted that gray whale populations were healthy and increasing in order to allay fears that responses, especially those involving whale mortality, would lead to restrictive management measures. In the present analysis, it has been assumed that all questionnaires were completed in good faith. Licence

[1] An earlier version of this paper was submitted to a special meeting on gray whales in 1990.

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holders were requested to return the questionnaire, regardless of whether or not they had any incidents involving gray whales to report. The questionnaire began with an inquiry about whether gray whales had ever been encountered during fishing operations. This was done to encourage responses regardless of whether or not gray whale collisions with gear had occurred. A request for records of all net or gear collision incidents with gray whales over the licence holder's entire fishing career followed. An incident was defined as a whale coming into physical contact with any fishing gear. To increase the total number of records, the time horizon was purposely left unbounded. It was thought that gray whale gear encounters should be relatively immune to the potential bias introduced by poor respondent recollection.

For each reported incident with a gray whale, the whale's status was recorded and classified as either: (1) dead; (2) swam away apparently uninjured – no gear damage sustained; (3) swam away apparently uninjured – gear damage sustained; (4) swam away injured; (5) swam away condition unknown; or (6) unknown.

Further questions referred to the number of years fished and the type of fishing gear. This information was used to stratify the responses and estimate the total mortality. Although in 1989 there were 8,160 licences issued, some vessels were licensed for more than one gear type (Dept. of Fisheries and Oceans, Licence Unit Statistics) and the questionnaire allowed for reporting of multiple gear types. If a licence holder used more than one gear type and the number of years fished for each type was not specified, a value was assigned to each type based on the best information available. Over 2,000 licence holders fished with both salmon drift gillnets and trolling gear. Most fished for all or most of the trolling season and used gillnets for approximately 30% of the gillnet season (S. Beckmann, DFO, Victoria, pers. comm., 1990). As a result, respondents indicating that they fished with both gillnets and troll gear were listed accordingly when assigning number of years fished. Except for shrimp trap gear, other fishing gear types are generally mutually exclusive and therefore the number of fishing years listed were divided equally among the gear types listed. Even though this may not be the case in all situations, seasons for most gear types overlap and individual boats usually only fish one gear type at a time. Any responses that did not include fishing years or gear specification, or where gear type could not be classified according to licence types were excluded from the analysis of the estimated mortality rate. For the purposes of this analysis, the identifications of gray whales were assumed accurate.

Other questions peripheral to the gray whale incidental mortality issue were included specifically to find the extent of gear damage and gather information about mortality of other cetaceans. Data from this portion of the questionnaire have also been used to estimate incidental mortality for small cetaceans along the BC coast (Stacey *et al*., 1997).

Stranding data

Information on gray whales was collected from three general sources: (1) cetacean stranding and collection records were examined at the Cowan Vertebrate Museum, University of British Columbia (UBC), the Royal British Columbia Museum (RBCM), the Marine Mammal Division, Pacific Biological Station, Department of Fisheries and Oceans, the Simon Fraser University, the University of Victoria and the Vancouver Public Aquarium; (2) records collected since 1987 through the Stranded Whale and Dolphin Program of BC; and (3) a request for information on gray whale entanglements and strandings that was sent to over 170 institutions, researchers, Universities, charter operations, lighthouse keepers and other individuals that may have been in a position to find or hear of dead gray whales, or who have previously worked in BC on marine mammals. To avoid duplicate reporting of a single stranding, we compared all dates for which animals were reported, examined available photographs and compared lengths, state of decomposition, distance between strandings and sex. All records presented were believed to be legitimate. Records of stranded gray whales were examined for evidence of an encounter with fishing gear, such as lines wrapped around any part of the body or markings on the skin. Where possible, for both published and unpublished records, original field notes were examined for evidence of collision with fishing gear. If the animal had been examined closely by the original observer and no such evidence was found, it was recorded as not having been caught. If the animal had been only superficially examined or was not examined at all and if it was impossible to tell if the whale had been incidentally caught from a study of the field notes, the cause of death was recorded as unknown. The ratio of those animals that had signs of being caught to those that had no evidence of it but were examined closely was then extrapolated to the unknown records.

Subsequent to the above survey, a series of annual reports from the Stranded Whale and Dolphin Program of BC were examined for comparison (Baird *et al*., 1991; 1994; Guenther *et al*., 1992; 1993; 1995; Willis *et al*., 1996) with the earlier results.

RESULTS

Questionnaire data

Of the 5,375 questionnaires sent out, 848 (16%) were returned. Of the 848, 729 were used; the remainder were excluded as they were incomplete. All records were entered into a database. The number of licence holders, the number of survey respondents, the percent reply and the total number of years fished, all according to gear type, are shown in Table 1.

Table 1

Questionnaire response rates by fishing gear type.

Gear type	No. license holders	No. responses per gear type	Percent reply	Total person yrs fished
Seine	548	77	14.1	1,659.5
Gillnet	3,230	399	12.4	5,492.5
Troll	3,232	438	13.6	8,357.0
Shrimp trawl	247	24	9.7	531.0
Groundfish trawl	142	6	4.2	135.0
Shrimp trap	867	30	3.5	342.0
Longline	435	127	29.2	1,396.0
Total	8,701	1,101[1]	12.7	17,913.0

[1]This differs from the total number of questionnaires received (848) because some respondents hold more than one licence. Also, responses not including the number of years fished or with incomplete responses regarding gear types are excluded.

The number of respondents who had encountered gray whales during their fishing operations was 404 (55.4%). Thirty-seven (5.1%) experienced incidents with gray whales with a total of 42 gray whale incidents (Table 2). Of these, three resulted in mortality, one each with salmon seine, salmon drift gillnet and longline gear. There was only one definite injury reported, in a troll incident, where the respondent noted the whale had 'some scratches'. In the most common end-result of an incident (11 cases e.g. 26.2%) the whale reportedly swam away in an unknown or unspecified condition. There were 12 incidents (28.6%) where no information was given on the outcome of the incident.

Based on the total number of incidents for each gear type and the number of licence holders for 1989, an annual estimate of about 20 collisions with fishing gear (including all possible outcomes) was derived (Table 3). The ratio of known mortalities to the number of gray whales that swam away after an incident (from Table 2) was extrapolated to the number of incidents with unknown outcomes. This estimate was added to the number of known mortalities for an estimated number of mortalities for each gear type (Table 3). From this the estimated annual mortality for each gear type was calculated based on the number of licence holders for 1989. The total estimated annual mortality was approximately two individuals. Of those gear types where mortality occurred, the mortality per total years fished was highest for salmon seine and lowest for salmon drift gillnet (Table 3).

Table 2

Number and type of gray whale incidents (collisions with fishing gear) from questionnaire. Incident types: 1= number incidents; 2 = number mortalities; 3 = number swam away with no gear damage; 4 = number swam away with gear damage; 5 = number swam away injured; 6 = number swam away unknown; 7 = number unknown.

	Incident types						
Gear type	1	2	3	4	5	6	7
Seine	7	1	1	1	0	0	4
Gillnet	19.23[1]	1	2	6	0	7	3.23[1]
Troll	13.77[1]	0	1	3	1	4	4.77[1]
Shrimp trawl	1	0	1	0	0	0	0
Groundfish trawl	0	0	0	0	0	0	0
Shrimp trap	0	0	0	0	0	0	0
Longline	1	1	0	0	0	0	0
Total	42	3	5	10	1	11	12

[1]The numbers listed for total incidents and unknown incidents for gillnets and troll gear are not whole numbers since one incident was reported by the respondent without distinguishing between these two gear types, and was thus divided among them based on the relative proportions typically fished for combination licence holders.

Table 3

Estimated gray whale mortality from questionnaire.

Gear type	Est. no. of mortalities	Mortality per total years fished[1]	Est. no. gear collisions per year[2]	Est. mortality per year[2]
Seine	3.00	0.0018	2.31	0.99
Gillnet	1.22	0.0002	11.31	0.72
Troll	0	0	5.33	0
Shrimp trawl	0	0	0.46	0
Groundfish trawl	0	0	0	0
Shrimp trap	0	0	0	0
Longline	1.00	0.0007	0.31	0.31
Total	5.22	0.0027	19.72	2.02

[1]This measure of catch per unit effort was calculated with the simplifying assumption that all gear types are equivalent for number of hours fished per season and for the quantity of gear in the water.
[2]Based on the number of licences for 1989.

Stranding data

All records collected prior to 1990 are presented in Table 4, with locations shown in Fig. 1. The dates noted are the earliest dates for each stranding; for many individuals, records from later dates were also available.

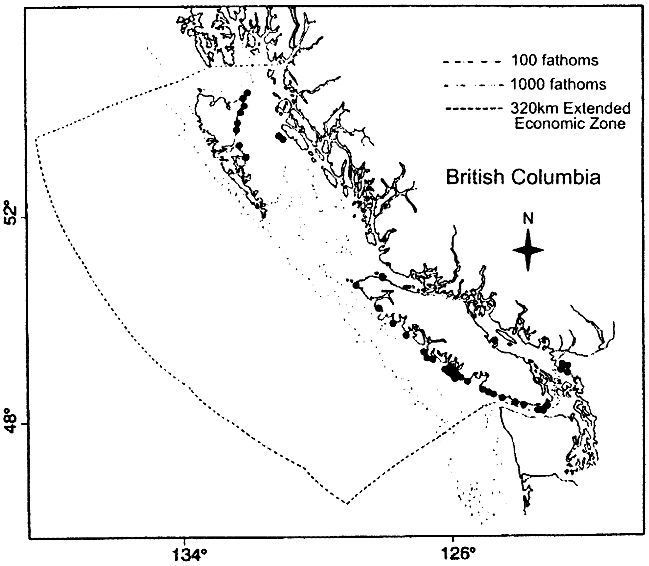

Fig. 1. Map showing locations of stranded and dead floating gray whales in BC. See Table 4 for details.

The cause of death was determined only for animals killed either in encounters with fishing gear, or in one case of two animals probably attacked by killer whales. Necropsies were not undertaken on many animals and even when they were, decay of the animal, or other factors, made positive determination of cause of death difficult. Of the 15 dead gray whales listed in Table 4 which were examined closely, cause of death for four (27%) was determined to be due to incidental catches in fisheries (but see Discussion for biases in this estimate).

Several records in Table 4 warrant further comment. Hatler (1972) mentions a photograph (No.60) (in a photo-duplicate file originally at UBC, now at RBCM) of an unpublished stranding of a gray whale from Long Beach, Vancouver Island, in the fall of 1957. However, examination of the photograph for this study revealed that although the photograph was labelled as a gray whale, the animal was in fact a sperm whale (*Physeter macrocephalus*). Campbell and Stirling (1971) mention a photograph of a stranded gray whale in the photo-duplicate file, but present no details. Further examination of photographs in this file indicate that this record is the same as that presented by Pike and MacAskie (1969), of an animal from August 1966 at Wreck Bay (also called Florencia Bay), on Vancouver Island. The file contains two records from this date, photo No.65 from near Green Point, Long Beach and No.427 from Wreck Bay. Hatler (1972) reported that the Long Beach animal (record No.65) had an estimated length of 40ft (12.19m). Examination of the photographs for this study revealed that these are duplicate records of a single animal, with a measured length of 27ft (8.24m) (presented in Pike and MacAskie, 1969).

The data for the 1990-1995 period (n = 40) are given in Table 5. These are considered in the Discussion section below.

Table 4
Records of stranded and dead floating gray whales received from sources other than questionnaire up to 1989 (VI=Vancouver Island).

Date	Location	Latitude/longitude	Cause[1]	Type[2]	Sex	Length[3]	Source[4]
16 Aug. 1966	Wreck/Florencia Bay, VI	49°0'N, 125°38'W	1	1	M	824	1, 2
1970s	Tofino, VI	49°9'N, 125°55'W	2	1	-	-	3[5]
Jun. 1971	Sandspit, Moresby I.	53°15'N, 131°48'W	2	1	-	-	4
25 Apr. 1976	Jordan River, VI	48°25'N, 124°3'W	2	1	F	-	2, 5
19 Jun. 1979	Rose Spit, Graham I.	54°10'N, 131°40'W	1	2	M	850	6[6]
19 Jun. 1979	Rose Spit, Graham I.	54°12'N, 131°38'W	1	2	F	790	6[6]
29 Dec. 1980	Bonilla I.	53°29'N, 130°38'W	1	3	-	442e	6
30 Mar. 1982	Cloose, VI	48°39'N, 124°48'W	2	1	F	862	2[7]
04 Mar. 1983	Vargas I.	49°11'N, 126°0'W	2	1	-	1,295e	6, 7[8]
17 Mar. 1983	Tatchu Pt, VI	49°51'N, 127°8'W	2	1	M	1,280	6
Apr. 1983	China Beach, VI	48°27'N, 124°10'W	3	4	F	-	8
16 Apr. 1983	Oenander R., Graham I.	53°39'N, 131°55'W	2	1	M	1,200e	7
17 May 1983	Estevan Pt, VI	49°22'N, 126°32'W	3	5	-	790e	6, 7
2 Mar. 1984	Vargas I.	49°9'N, 125°59'W	2	1	-	660e	6, 9[9]
8 Mar. 1984	Metchosin, VI	48°25'N, 123°28'W	1	1	F	800e	8, 10[10]
24 Apr. 1984	Boundary Bay	49°3'N, 122°56'W	3	4	F	950e	6, 10
26 Apr. 1984	Boundary Bay	49°4'N, 123°0'W	2	1	-	850e	6, 10
4 Jun. 1984	White Rock	49°1'N, 122°48'W	2	1	F	909	6, 10
5 Jun. 1984	Boundary Bay	49°5'N, 122°54'W	2	1	-	600e	6, 10
9 Sep. 1984	West Coast Trial, VI	48°40'N, 125°W	2	1	-	-	11
20 Jan. 1985	Bonilla I.	53°29'N, 130°37'W	2	1	-	-	8
Sep. 1985	Side Bay, VI	50°20'N, 127°52'W	2	1	-	792e	8[11]
16 Apr. 1986	Tofino, VI	49°7'N 125°54'W	2	1	M	900e	6, 12
May 1987	Estevan Pt, VI	49°23'N, 126°31'W	2	1	-	-	6, 13, 14
1 Sep. 1987	Kyuquot, VI	50°N, 127°20'W	2	1	-	1,370e	6, 13, 14
17 Sep. 1987	Long Beach, VI	49°2'N, 125°40'W	2	1	-	610	6, 13
7 Oct. 1987	Tofino, VI	49°10'N, 125°55'W	2	6	-	760e	6
1 May 1988	Bonilla Pt, VI	48°35'N, 124°43'W	1	1	-	680	15[12]
19 May 1988	Denman I.	49°30'N, 124°41'W	1	6	M	750	15[13]
24 May 1988	Graham I.	53°30'N, 131°50'W	2	1	-	-	15
4 Aug. 1988	Cape Scott, VI	50°47'N, 128°21'W	3	4	-	800e	16
20 Aug. 1988	Goletas Ch., VI	50°50'N, 127°45'W	2	1	-	800e	6, 15[14]
Jan. 1989	Estevan Pt, VI	49°23'N, 126°30'W	2	1	-	-	16
Jan. 1989	Cape Fife, Graham I.	54°5'N, 131°40'W	2	1	-	-	16
Jan. 1989	Cape Fife, Graham I.	54°5'N, 131°40'W	2	1	-	-	16
1 Jun. 1989	Cumshewa Hd, Moresby I.	53°1'N, 131°33W	2	6	-	-	16
6 Jun. 1989	Echachis I.	49°7'N, 125°56'W	2	1	-	1,250e	16
7 Jun. 1989	Sooke, VI	48°19'N, 123°40'W	1	1	M	1,260	16[15]
5 Jul. 1989	Pachena Pt, VI	48°43N, 125°5'W	1	1	M	-	6, 16
23 Aug. 1989	Ucluelet, VI	48°57'N, 125°35'W	2	6	-	-	16
29 Oct. 1989	Sooke, VI	48°19'N, 123°40'W	1	6	F	1,200e	16[16]

[1] 1 = examined closely by original observer with no signs of incidental catch; 2 = not examined closely; 3 = incidental catch.
[2] 1 = found dead on beach, no obvious cause of death; 2 = found dead on beach, possible cause of death due to killer whale attack (body extensively covered with tooth rakes); 3 = live stranding, died - note the total length indicates a new born calf; 4 = lines wrapped around tail and/or body, possibly from trap or troll fishery; 5 = gillnet wrapped around tail; 6 = found floating dead, no obvious cause of death.
[3] If the length was estimated or it was unclear that length was standard, then the measure (in centimetres) is followed by 'e'.
[4] 1. Pike and MacAskie, 1969; 2. Royal British Columbia Museum; 3. A. Barton, Simon Fraser University; 4. N.&A. Carey; 5. Darling, 1977, p.40; 6. Notes and/or photographs in files of M. Bigg, Pacific Biological Station; 7. Goodman, 1984; 8. Stranded Whale and Dolphin Program of BC, c/o authors; 9. Bamfield Marine Station; 10. Canada, 1985; 11. Pacific Rim National Park; 12. Mansfield, 1987; 13. Baird *et al.*, 1988; 14. Canada, 1988; 15. Stacey *et al.*, 1989; 16. Langelier *et al.*, 1990.
[5] Skull in Simon Fraser University Zooarcheology Collection, Burnaby, BC. No. T00307.
[6] Partial skeletons at Queen Charlotte Islands Museum, Skidegate, BC. Both animals had extensive tooth rakes and bite marks, and appeared to have been attacked by killer whales.
[7] Skull at Royal British Columbia Museum, Victoria, BC. (BCMP No. 11310).
[8] Goodman (1984), based on data compiled by M. Bigg, reports the length of this animal as 27' (820cm). Notes in the files of M. Bigg, however, identify this animal as being measured at 42.5' (1,295cm).
[9] Skeleton at Bamfield Marine Station, Bamfield, BC.
[10] Skeleton collected by International Cetacean Watch Society, skull and partial skeleton at Sidney Marine Mammal and Historical Museum, Sidney, BC; partial skeleton at Stranded Whale and Dolphin Program of BC.
[11] Skull at Nanaimo Montessori School, Nanaimo, BC
[12] Skeleton at Wickaninish Interpretive Center, Pacific Rim National Park, BC.
[13] Skull at North Island Wildlife Recovery Center, Errington, BC, collected by Stranded Whale and Dolphin Program of BC. (SWDP No. 88-05).
[14] Skull at Stubbs Island Charters, Telegraph Cove, BC. (SWDP No. 88-10).
[15] Skeleton at Edward Milne School, Sooke, BC. (SWDP No. 89-10).
[16] Skeleton at Lester B. Pearson College of the Pacific, Victoria, BC. (SWDP No. 89-29).

DISCUSSION

Questionnaire data

For a general discussion of the use of questionnaire surveys in such studies, see Lien *et al*. (1994). The 16% response rate to the questionnaire represents a relatively high return for studies of this nature (*cf*. Heide-Jørgensen, 1988). Potential bias resulting from non-response patterns is difficult to control in this type of survey. A certain measure of resilience to the unknown influence of those who did not respond can be taken from the proportion of responses in each fishing gear category. As Table 1 indicates, the return rate is the same across the three largest fisheries: seine, gillnet and troll, and varies only in the smaller groups. The lowest return rate came from the shrimp trap fishery. Although there are no records of gray whales entangled in shrimp trap gear, a humpback whale became entangled in shrimp trap gear in 1989 (Langelier *et al*., 1990). Some respondents did not specify which type of trap or trawl they used and the records were subsequently excluded from the analyses. This probably accounts for the low response for these categories. As trap and longline gear is set for up to two days without being monitored by the fishermen, gray whale entanglements with those gear types could remain unrecorded, when, for example, gear would disappear for no obvious reason. However, no data are available to estimate the magnitude of this bias. A bias in extrapolating from the total number of licences issued is that many fisheries are limited entry fisheries and some fishermen apply for licences without using them, to retain the ability to use the licences in the future. Again, no data are available to estimate the proportion of licences not being used, but this would tend to result in an overestimate of gray whale mortality.

Other biases inherent in social surveys include limitations of recall, inclusion of socially or politically desirable responses, or simply a cultural bias against perceived management intrusion within the fishing society (Lien *et al*., 1994). The latter two possibilities represent a strategic response bias. Given the relatively high rate of return, the number of respondents that included their name and address and the number of additional and helpful unsolicited comments, the information received is believed to be accurate and largely free from uni-directional bias.

Fishermen may have regarded this as a good opportunity to voice their concerns about gear damage due to whale incidents, which would have biased the number of incidents reported upwards. On the other hand, fishermen may not have wanted to make it known that gray whales or other cetaceans were coming into contact with their gear, especially when it resulted in injury or death to the animal. Heide-Jørgensen (1988), in discussing his mailed survey regarding killer whales in Greenland, remarks that the small response to his questionnaire (7%) may have been due to people not being inclined to return a questionnaire when they have no information to provide. This potential bias may have been offset in the survey used for this study by the inclusion of question No.1. Many respondents could have answered it affirmatively and thereby felt that they were contributing some information.

In designing the survey, it was assumed that there would be a trade-off between the ease of filling out a questionnaire and the magnitude of the response to it. To obtain more detailed data from the questionnaire regarding gear type, years fishing, identification of animals involved in gear collisions and resultant mortality, specific categories could have been included. However, with the anticipated low number of gray whale incidents, inclusion of such details would result in a decrease in the number of responses, to the point that the resultant mortality estimate would have been less accurate.

Some inaccuracy may result from the inability of the observer to assess the amount of injury, especially internal or stress-related, associated with incidents. An underestimate of mortality may be present due to the fact that a percentage of animals in the category ‘released unharmed’ probably suffered some injury of this nature. Therefore, this category may contain some animals that later died as a result of the incident. Mortality at a later date due to entangled gear might also occur, as evidenced by a gray whale reported by Geiger and Jeffries (1983), which apparently entangled in a shark gillnet off California and drowned in Washington when the net snagged on bridge supports. Similarly, Table 5 reveals two animals that had died later, one entangled in a Mexican gillnet fishery and one possibly in a US swordfish (*Xiphias gladius)* net in 1994.

An additional potential bias in the results arises from the ability of the respondents to identify gray whales accurately. Included in the questionnaire was a question asking about entanglements of other species of cetaceans. Responses were received of gear collision incidents with 350 small cetaceans (Stacey *et al*., 1990; 1997), as well as with 11 humpbacks (*Megaptera novaeangliae*) and 10 killer whales (*Orcinus orca*). There were also reports of incidents involving 13 unidentified cetaceans, 10 of them large whales. Two additional species, one minke whale (*Balaenoptera acutorostrata*) and one sei whale (*B. borealis*) were mentioned by respondents recalling secondhand reports of incidents. In light of these responses showing the ability of at least some fishermen to discriminate between species of large whales, it was assumed that the identifications of gray whales were accurate. We did not pro rate the unidentified large cetacean records using the relative proportion of gray whales to other large cetaceans because of possibly incomplete data, as many respondents might not have fully completed the questionnaire if they did not have any gray whale incidents to report in question No.2. It is likely that some of the unidentified animals were gray whales but, considering that some of the records identified as gray whales may have been misidentified, it was not possible to predict the direction or magnitude of these biases.

Stranding data

Biases in previously collected stranding data render its usefulness in evaluating true levels of incidental mortality questionable. However, a properly designed future study could answer such questions more efficiently. Knowledge of mortality levels from independent sources such as questionnaire surveys are important in understanding what proportion of animals killed in fishing gear either sink, are eaten by scavengers, float offshore, or strand but are never found. Thus, the examination of stranded animals will only provide a minimum estimate of animals killed in fisheries. One consideration is the geographical scope involved when examining stranded animals. Some animals killed in fisheries in BC will probably wash up to the north in Alaska or to the south in Washington State. Similarly, some animals which wash up in BC have probably been killed in US fisheries. Presumably however, if efforts and type of fishing are similar in all three areas, such biases would not be uni-directional. There used to be little effort put into monitoring strandings in southeast Alaska, so such events there are probably not recorded (J. Sease, NMFS, Juneau, pers. comm., 1990). In Washington State, floating dead whales are not typically recorded unless they wash up on

Table 5

Strandings and incidental catches of gray whales from 1990-1995. V.I. = Vancouver Island.

Date[1]	Location[2]	Comments[3]
25 Mar 1990	Hesquiat Harbor, V.I.	C,u
05 Apr 1990	Kettle In., Aristazabal I.	C,u
18 Apr 1990	Esperanza In., V.I.	F,u
28 May 1990	Raft Cove, V.I.	C,u
31 May 1990	S Sombrio Pt., V.I.	C,u
01 Jun 1990	Ferrer Pt., Nootka I.	C,u
06 Jun 1990	South Beach, Graham I.	C,f
11 Jun 1990	Kitasu Bay, Swindle I.	A (herring net pen),u
27 Jun 1990	Miller Creek, Graham I.	C,f
29 Jun 1990	Weibe I.	C,D,u
01 Jul 1990	Hecate Strait	C,u
18 Jul 1990	2 mi. E. Lookout I.	C,f
24 Jul 1990	Lennard I.	C,f
26 Jul 1990*	7 mi. W Cape Beale, V.I.	C,u
20 Mar 1991	Hesquiat, V.I.	C,m
23 Mar 1991	Cleland I.	E (herring set gillnet)
27 Apr 1991	Pulteney Pt., Malcolm I.	C,f
12 May 1991	Boundary Bay	C,f
11 Jul 1991	Nuchatlitz Inlet, Nootka I.	C,m
18 Jul 1991	Orveas Bay, V.I.	C,m
29 Apr 1992	Stanley Park, English Bay	F? (27 April),m
24 May 1992	Cape Perkins, V.I.	C,m
1 Jun 1992	Port Clements, Graham I.	C,f,P
3 Jun 1992	Union Bay, V.I.	C, m
Ca 17 Jun 1992	Tlell, Graham I.	C,D,u
31 Aug 1992	Radar Beach, V.I.	C,m
19 Dec 1992	Higgins Passage, Price I.	C,D,f
1 May 1993*	~ 46km WSW Tofino, V.I	C,D,u
8 Aug 1993	Smith Inlet	E (salmon drift gillnet),u
17 Apr 1994	Dare Point, V.I.	A,D,u,814cm (Mexican gillnet fishery)
27 Apr 1994	2km S Dare Point, V.I.	C,D,u,1158cm
5 May 1994	Port San Juan, V.I.	A,D,u,(US swordfish net?)
13 May 1994	Nootka I.	C,D,u
3 Jun 1994	Jordan River, V.I.	C,D,f,730cm
8 Jun 1994	N Eagle Creek, Graham I.	C,D,u
8 Apr 1995	Winter Harbour, V.I	C,u
14 Apr 1995	Jordan River, V.I.	C,D,u
June 1995	Kitasu Bay	C,D,u
18 Jun 1995	Boundary Bay	C,D,u
10 Jul 1995	Off Winter Harbour, V.I.	C,D,u

[1]Date shown is earliest date reported. Many records were also reported seen either on shore or floating from later dates. Similarly, some animals may have been dead for up to a month when first reported. [2]Location is last known location. In some cases, animals were seen floating on one day, with later reports of what we believe is the same animal washed up nearby. [3]Comments: Length shown if known. A: incidental catch, died; B: live stranded, died; C: found dead; D: not recovered; E: incidental catch, released alive; F: live stranded, returned to water alive; sex: f=female, m=male, u=unknown. *Some doubt over identity of animal. Precise location details can be obtained from the Stranded Whale and Dolphin Program of British Columbia.

shore (R.C. Ferrero, NMFS, Seattle, pers. comm., 1990). This is another source of error leading to a low estimation of deaths and thus of incidental mortality. In addition, animals may wash up in one location and be recorded, then wash back out and be recorded elsewhere. Such biases are exacerbated by the lack of tagging of dead animals for re-identification and by a lack of communication between stranding programmes in the two adjoining countries. More recently, effort has been put into looking at mortalities and fishery interactions in the USA (see Angliss *et al*., 2001, table 24a,b).

Another potential bias in this method is that some signs of an incidental mortality, such as nets or lines wrapped around part of a whale, would be extremely obvious even if an animal was not examined closely. Such signs may be visible months after the animal washed up on a beach. However, there have been no circumstances where an animal observed killed in fishing gear in BC has subsequently washed ashore and was examined. Several additional complications may also be important in determining cause of death. Some animals can be killed with little or no external signs of injury or associated entangled gear. Heyning and Lewis (1990) note two incidents off California which are relevant. In one case the net from an entangled dead floating gray whale was removed and the animal stranded the next day. However, it was impossible to determine the cause of death, even though the animal was examined closely. In another case, a dead floating animal seen with gear attached stranded 11 days later without gear. It is also possible that animals could get fishing gear entangled around an appendage without serious harm. Such gear might stay entangled indefinitely and animals dying from other causes would be recorded as killed incidentally in fishing gear. Moore *et al*. (1979) also noted that in areas with strong currents or high water flow (such as in river mouths), gray whales that had died from other causes could become entangled in gear; moribund gray whales dying from other causes might be less likely to actively avoid entangling in gear if such a situation arose. Thus, although the final cause of death might be from gear entanglement, mortality would have been inevitable. For these reasons it is not possible to predict the magnitude or direction of these biases and for the purposes of these analyses, it was assumed that animals with gear entangled on them died as a result.

The level of effort expended to record strandings varies along the 27,000km of BC coastline. Only two of the strandings reported in Table 4 are from the mainland coast of BC north of Vancouver Island, where effort is much lower than in the rest of the province. The large number of gray whale records towards the end of the period probably does not reflect an actual increase in the number of strandings, but rather increased effort. However, despite a considerable increase in effort, it is likely that only a small percentage of the animals washing up are recorded. Comparing stranding programmes elsewhere in North America and their levels of effort and the accessibility of coastline, the proportion of the total number of strandings in BC which get recorded is probably relatively low. The majority of the effort in responding to strandings has also been focused on more unusual species, or on species with higher research priorities, (e.g. killer whales) and on those in more accessible areas. However, the remains of large whales, such as the gray whale, may stay on a beach for months or years and thus the likelihood of them eventually being found and reported is higher than for smaller animals.

The number of gray whales reported dead each year can probably be best estimated from years when such events receive considerable publicity, or from more recent years as effort and awareness has increased. In 1984, following a chlorophenate spill in the Serpentine River near White Rock, BC, six gray whales were reported washed up dead in southern BC and an additional four animals were found in Washington State (Canada, 1985; Knox, 1985; Colodey, 1986; Table 4). Although no cause/effect relationship was found, such events appear to generate general public awareness, especially through the media and probably result in an increase in reporting. Although only a few stranded gray whales were recorded in 1985 and 1986, based on the number of strandings of other species recorded during those years (Stranded Whale and Dolphin Program of BC, unpubl. data) we believe this reflects a lack of effort in recording strandings, rather than an actual decrease in the number of strandings. Based on a consideration of the low levels of effort in reporting and recording strandings, we believe the number recorded in 1989, nine individuals, best represents the typical number of gray whales washing up each year. This is supported from two sources. Firstly, Heyning and Dahlheim (In Press) noted that less than 5% of the estimated 1,407 gray whales that die annually in the eastern North Pacific are recorded in stranding records along the North American coast. Unless a highly disproportionate number die in even more isolated areas, such as in much of Alaska, the highest number recorded in one year from BC waters is still probably conservative. Secondly, effort in promoting the reporting of strandings in BC increased since 1987, as have the total number of all cetacean strandings. For example, the number of gray whale strandings recorded from 1990 − 1995 was about 40 individuals (Table 5) or about 7 per year. On this basis, the estimate of nine individuals is not unreasonable. Using this estimate of nine individuals and the estimated rate of 27% of such strandings resulting from incidental catches in fisheries, gives a crude estimate of minimum annual mortality of 2.4 individuals.

Of the four incidental catch records listed in Table 4, three appeared to have taken place during the northward migration and the fourth during the summer. Very little fishing is undertaken during the period of the southbound migration.

Several additional non-natural sources of mortality should be taken into account. One of these is mortality from collisions with vessels; for example, Moore *et al*. (1979) note one stranding off Washington State where vessel collision was implicated. Angliss *et al*. (2001) reported a ship strike in Alaska in 1997. Although this issue was not directly addressed in the questionnaire, there was no evidence from the stranding and questionnaire data that collisions with vessels might be an important mortality source in BC. An additional mortality source may be collisions with net pens used in aquaculture or fisheries, such as the herring spawn on kelp fishery in BC. Net pens used in salmon farms are typically located in areas which gray whales do not frequent, so few conflicts are likely to occur. Herring net pens on the other hand are set in areas where herring spawn and gray whales feed in these areas on roe. There is, for example, one record from June 1990, of a gray whale entangling and drowning in a herring pen on the central BC coast (P.F. Olesiuk, DFO, Nanaimo, pers. comm., 1990; Baird *et al*., 1991). No other incidents are known of collisions with herring pens, but monitoring of this fishery for potential conflicts with gray whales is warranted. No reports of collisions with herring set gillnets were noted in the questionnaire returns, although some animals have probably been killed in this fishery; a live animal was photographed entangled in a herring set gillnet in March 1991 off Tofino, Vancouver Island (RWB own data).

CONCLUSIONS

Based on the results of the two methods, an estimate is derived of between 2 and 2.4 gray whales killed incidentally in BC commercial fisheries each year. Although there are some doubts as to the validity of questionnaire data (e.g. IWC, 1991), the estimate based on stranding data to some degree corroborates the use of the questionnaire survey in this case. However, there are numerous biases in both methods. Despite these biases, as Heyning and Lewis' (1990) examination of the incidental take off California, we conclude that the incidental take in Canadian waters appears to be very small relative to the population size. Even if both methods produced estimates an order of magnitude lower than actual incidental mortality, this would still be the case.

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