NORTHWEST STRAITS
marine conservation initiative

RATES OF MARINE SPECIES MORTALITY CAUSED BY DERELICT FISHING NETS IN PUGET SOUND, WASHINGTON

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Abstract

Lost or abandoned fishing nets made of synthetic materials may persist in the marine environment for years or even decades and have been shown to continue to entangle and kill target and non-target species. Although animals observed during the recovery of derelict nets can provide information on species impacted, they only represent a portion of the total mortality caused by the gear. In order to estimate annual mortality, estimates of species catch rates and rate of decomposition or recycling by other animals is necessary.

During the spring and summer of 2007 the Northwest Straits Initiative and Natural Resources Consultants, Inc., began a derelict net monitoring project in the Puget Sound, Washington, to study the rates at which derelict gillnets entangle marine animals and the decomposition processes those animals undertake after entanglement. A minimum of three dive surveys were conducted on four derelict nets prior to net removal. During these surveys a total of 215 entangled animals were observed: 158 invertebrates, 33 seabirds, and 24 fish. Catch rates for invertebrates, mainly crab, averaged 3.06 animals per day (n=107, 95% C.I. 2.97-3.15). Average fish catch rates were 0.42 animals per day (n=16, 95% C.I. 0.41-0.43) and consisted of spiny dogfish sharks (*Squalus acanthias*), lingcod (*Ophiodon elongates*), spotted ratfish (*Hydrolagus colliei*) and five fish that could not be identified due to decomposition. Seabirds, mainly cormorants (*Phalacrocoracidae sp.*), were caught at an average rate of 0.24 animals per day (n=9, 95% C.I. 0.19-0.21).

Of 63 fresh live invertebrates encountered in the surveys, 34 (54.0%) were completely decomposed in an average of 5.43 days (n=34, 95% C.I. 5.40-5.45), 21 (33%) remained alive up to 8.0 days (n=21, 95% C.I. 7.96-8.05), and eight (13%) died and were in varying states of decomposition over an 8.0 day period. One live fish entangled was completely decomposed with 3.02 days. Of seven freshly dead fish encountered, four (57%) were completely decomposed in an average of 4.45 days (n=4, 95% C.I. 4.42-4.48). However, bones from several fish persisted in the derelict net for up to 15 days. Only two partially decomposed seabirds were observed during the surveys and one transitioned to bones in 2.96 days and the other remained in essentially the same partially decomposed condition for 7.94 days. The decomposition rates of animals increased when sunflower stars (*Pycnopodia helianthoides*), a predatory invertebrate, were observed on or near the tagged animals.

During final derelict net recovery dropout rates for animals in each physical condition category were calculated. Dropout rates can be used to adjust data from previously removed nets to more accurately reflect the numbers of species impacted compared with those observed on deck. Dropout rates ranged from 5.9% for live animals, 14.3% for freshly dead animals, 13.3% for partially decomposed animals and 33.3% for bones or shell pieces.

Derelict net catch rate and animal decomposition rate data would benefit from additional derelict net tagging experiments over a longer period of time with more dive surveys. Further decomposition studies conducted in semi-controlled environments would be useful to better observe the decomposition process.

Introduction

Standard protocol for the removal of derelict fishing gear (DG) in Puget Sound involves a thorough inventory of the entangled animals and documentation of each animal's general physical condition upon gear retrieval. This method produces information about the DG's capabilities for entrapping and killing animals during a single point in time, but it does not account for animals that have become entangled, died and been eaten or decomposed since the gear was lost. It is safe to assume that animals encountered in each DG item on the day of removal are only a fraction of the overall catch, since in many cases the recovered DG item has been actively trapping animals for several months and/or years. Animals have also been observed becoming disentangled and dropping out of the gear during removal, therefore going unaccounted for in the final inventory performed on deck. Divers attempt to inventory and report entangled animals during DG recovery but often miss some animals when concentrating on net removal.

As of yet, there have been no studies done to quantify the long-term impact of derelict fishing gear on marine life in the Puget Sound. The purpose of this study was to observe and document animal decomposition processes during entanglement and determine preliminary catch rates and drop-out rates. Gaining this knowledge will significantly increase our understanding of the long-term threat derelict nets poses on the Puget Sound marine environment.

Methods

Using the derelict fishing gear master database provided by the Washington Department of Fish and Wildlife (WDFW), four derelict gillnets were chosen for the project. The selection of derelict gillnets was based on size, location, type of habitat and depth of water (Table 1).

Table 1: Gear location, length and width (feet), minimum and maximum depth (feet) and type of habitat.

GEAR ID	LOCATION	LENGTH(ft)	WIDTH(ft)	DEPTH MIN (ft)	DEPTH MAX (ft)	HABITAT
3969	Lopez Island	1000	60	52	60	Rocky reef
3957	San Juan Is, Eagle Point	300	50	57	85	High relief rocky reef face near kelp forest
3971	San Juan Is, Cattle Point	1000	80	41	90	Boulders on sand slope
4564	Point Roberts	150	3	33	40	Boulders on sand flat

Each net chosen differed in at least two of these categories, allowing the examination of impacts from DG on a variety of Puget Sound marine environments. Although the derelict nets were chosen based on their size and habitat attributes, they were chosen prior to diving and the selection was not biased by the number or species of animals entangled. Catch rate, decomposition rate and dropout rate data were grouped for all four nets for data analysis.

Multiple dive surveys on each of the four nets were conducted prior to removal after the final survey. During the initial dive, professional divers using surface-supplied air visually surveyed each net. Once an entangled animal was encountered the diver attached a stainless steel longline clip with an individually numbered tag in the net at the location of the animal. Using an underwater communication system, the diver then reported the tag number, common name, and a brief description of the animal's physical condition. The five categories used to describe the physical condition are as follows: Fresh live (FL), fresh dead (FD), rotten or partially decomposed (R/PD), bones or shell parts (B/SP), and completely gone (CG). This information was reported for each entangled animal and was logged on the deck of the operation vessel. On subsequent dives, the divers followed the same procedure, adding additional tags to newly entangled animals and describing the condition of previously tagged animals. The divers noted the presence of any potential predators near the location of entangled animals. Subsequent dive survey schedules were dependent upon weather and scheduling of normal DG removal work in the area and survey intervals varied for individual nets and between nets. Observations during dive surveys and removal suggest that an animal's rate of decomposition significantly increases when entangled animals are preyed upon by sunflower stars (*Pycnopodia helianthoides*). Sunflower stars are common on many of the derelict nets encountered in Puget Sound. Divers noted the presence of sunflower stars near a number of individually entangled animals.

Net removal took place immediately following the final survey of each net. During net removal the dive support vessel was anchored while a single diver removed the net from the seabed by hand and attached airlift bags to the net to lift it vertically off the seabed to the surface where it was then collected by the support vessel. Onboard biologists carefully examined the net for numbered tags and entanglements of animals and recorded the physical condition of each animal. After all animals and tags were accounted for, both live and dead animals and as much algae and plant growth as possible were removed from the net and returned to sea.

Catch rates were calculated from the number of animals entangled between survey periods. Decomposition rates were calculated from the change in physical condition of animals between surveys. Dropout rates were determined from the difference in the number of tagged animals observed by the divers on the final survey and the number of tagged animals that arrived on deck after gear removal.

A total of five surveys (including initial and final) were conducted on net #3969 within a twenty-eight day time frame from May 24 to June 21, 2007. Nets #3957 and #3971 were surveyed three times during the same eight-day period from August 15 to August 23, 2007. Net #4564 was surveyed three times in a seven-day period between September 5 and September 12, 2007. Table 2 shows the date and times of each dive survey for each net and the time elapsed between surveys.

Table 2: Survey intervals for the derelict gillnets.

GEAR ID 3969	Survey Date	5/24/2007 10:00am (initial)	6/8/2007 3:00pm	6/11/2007 9:30am	6/15/2007 9:30am	6/21/2007 10:00am (final)
	Elapsed time since 1st survey (days)		14.98	18.21	21.98	28.00
	Elapsed time since 2nd survey (days)			3.23	7.00	13.02
	Elapsed time since 3rd survey (days)				3.77	9.79
	Elapsed time since 4th survey (days)					6.02
GEAR ID 3957	Survey Date	8/15/2007 10:05am (initial)	8/18/2007 10:30am	8/23/2007 10:00am (final)		
	Elapsed time since 1st survey (days)		3.02	8.00		
	Elapsed time since 2nd survey (days)			4.98		
GEAR ID 3971	Survey Date	8/15/2007 3:00pm (initial)	8/18/2007 2:00pm	8/23/2007 1:30pm (final)		
	Elapsed time since 1st survey (days)		2.96	7.94		
	Elapsed time since 2nd survey (days)			4.98		
GEAR ID 4564	Survey Date	9/5/2007 10:00am (initial)	9/7/2007 3:00pm	9/12/2007 10:30am (final)		
	Elapsed time since 1st survey (days)		2.21	7.02		
	Elapsed time since 2nd survey (days)			4.81		

Results

Catch Rates

A total of 215 animals were found entangled in the four nets during the study. Invertebrates accounted for the majority of the animals encountered with 158 (155 crab, 2 sea urchin, 1 abalone). Totals for seabirds and fish were significantly smaller at 33 and 24, respectively. Although several marine mammals have been found during previous derelict gillnet removals, none were encountered during the study. Table 3 lists the total animals caught by species.

Table 3: Number of animals by species entangled in the four derelict gillnets studied.

Common Name	Scientific Name	# in 1st Dive	# in Subsequent Dives	Total Number Caught
Red Rock Crab	*Cancer productus*	41	67	108
Dungeness Crab	*Cancer magister*	2	28	30
Golfball Crab	*Rhinolithodes wosnessenski*	0	8	8
Puget Sound King Crab	*Lopholithodes mandtii*	4	1	5
Northern Kelp Crab	*Pugettia producta*	1	1	2
Hermit Crab	*Paguridae sp.*		1	1
Longhorn Decorator Crab	*Eualus avinus*	1	0	1
Green Sea Urchin	*Strongylocentrotus droebachiensis*	1	0	1
Red Sea Urchin	*Strongylocentrotus franciscanus*	1	0	1
Northern Abalone	*Haliotis kamtschatkana*	1	0	1
Total Invertebrates		**52**	**106**	**158**
Lingcod	*Ophiodon elongatus*	1	2	3
Kelp Greenling	*Hexagrammos decagrammus*	3	0	3
Spotted Ratfish	*Hydrolagus colliei*	1	2	3
Spiny Dogfish Shark	*Squalus acanthias*	0	7	7
Fish Unidentified		3	5	8
Total Fish		**8**	**16**	**24**
Common Loon	*Gavia immer*	2	0	2
Grebe Unidentified	*Podicipedidae sp.*	2	0	2
Cormorant Unidentified	*Phalacrocoracidae sp.*	20	9	29
Total Seabirds		24	9	33
TOTAL ANIMALS		**84**	**131**	**215**

For each net, catch rates (animals/day) were calculated by species at each dive interval after the initial survey. Animals found during the initial dive surveys were not included in determining catch rates. Each species was then categorized into one of three groups; invertebrates, fish, or seabirds. Catch rates (number of animals per interval day) for each animal group were averaged across all survey intervals and for all four study nets combined (Table 4). An average of 3.06 invertebrates/day (n=107, 95% C.I. 2.97-3.15) were caught by the four derelict nets over the course of the study. Crab represented all of the invertebrates caught after the initial survey dominated by 67 (63%) red rock crab (*Cancer productus*), 28 (26%) Dungeness crab (*Cancer magister*), eight (7%) golfball crab (*Rhinolithodes wosnessenski*), one (1%) Puget Sound king crab (*Lopholithodes mandtii*), one (1%) northern kelp crab (*Pugettia producta*) and one (1%) unidentified hermit crab (*Paguridae sp*.).

A total of 16 fish were caught after the initial surveys for an average catch rate of 0.42 fish/day (n=16, 95% C.I. 0.41-0.43) (Table 4). Fish caught included seven (44%) spiny dogfish shark (*Squalus acanthias*), two (12%) lingcod (*Ophiodon elongates*), two (12%) spotted ratfish (*Hydrolagus colliei*) and five (31%) fish that could not be identified due to decomposition.

Nine seabirds were caught in the four gillnets after the initial surveys for an average catch rate of 0.21 seabirds/day (n=9, 95% C.I. 0.19-0.21). All of the seabirds caught were cormorants (*Phalacrocoracidae sp.*).

Table 4: Overall Daily Catch Rates (number of animals per day) by Species Group

Catch Per Day	Number	Min	Max	**Average**	Standard Deviation	95% Confidence Interval
Invertebrates	107	0.20	14.93	3.06	4.57	2.97-3.15
Fish	16	0.00	2.36	0.42	0.76	0.41-0.43
Seabirds	9	0.00	0.67	0.21	0.26	0.19-0.21

Decomposition Rates

Out of the total 215 animals entangled in the four derelict gillnets studied, 138 (64%) were used for decomposition rate studies. Those animals originally found during final dive surveys (62) and those whose tags were lost after initial documentation (15) were not used to determine decomposition rates due to insufficient data. Animals were grouped by taxonomic group, seabird, fish and invertebrate and the average number of days observed for animals to change from one decomposition category (fresh whole live, fresh whole dead, partially decomposed, bones or shells and completely gone) to the next was calculated with and without the presences of sunflower stars and combined.

Invertebrates

A total of 109 invertebrates (mostly crab) were tagged and documented prior to final surveys, however eight animals were omitted from decomposition studies due to loss of corresponding number tags resulting in insufficient data.

Fresh Live

Of the 63 fresh live invertebrates encountered, 34 (54%) were completely gone in an average of 5.43 days (n=34, 95% C.I. 5.40-5.45). Sixteen (47%) of the 34 invertebrates that were completely decomposed had sunflower stars at their location and were completely gone within 4.81 days (n=16, 95% C.I. 4.80-4.82) (Table 5). Two (3%) of the 64 fresh live invertebrates transitioned to shell parts in an average of 5.12 days (n=2, 95% C.I. 5.00-5.23). Three invertebrates went from fresh live to rotten/partially decomposed in an average of 7.51 days (n=3, 95% C.I. 7.42-7.60), and another three invertebrates went from fresh live to fresh dead in an average of 8.28 days (n=3, 95% C.I. 8.13-8.44). Twenty-one (33%) of the 64 fresh live invertebrates remained alive over an average of 8.0 days (n=21, 95% C.I. 7.96-8.05).

Fresh Dead

Of the 25 invertebrates first encountered as fresh dead, 14 (56%) were completely gone in an average of 5.96 days (n=14, 95% C.I. 5.93-5.98) (Table 5). Sunflower stars were observed at the location of 8 (57%) of these 14, with an average time to completely gone of 5.32 days (n=8, 95% C.I. 5.30-5.34). Seven (28%) of the 25 fresh dead invertebrates transitioned to shell parts within 6.73 days (n=7, 95% C.I. 6.71-6.75), six of which had sunflower stars at their location. One fresh dead invertebrate transitioned to rotten/partially decomposed in 8.00 days, and three animals (12%) remained at fresh dead without signs of further decomposition in an average of 7.96 days (n=3 95% C.I. 7.96-7.96).

Rotten/Partially Decomposed

Of the 13 rotten/partially decomposed invertebrates encountered, four (31%) were completely gone in an average of 6.71 days (n=4, 95% C.I. 6.63-6.79) (Table 5). Two of these 4 had sunflower stars at their location and were completely gone within 5.48 days (n=2, 95% C.I. 5.48-5.48). Four (33%) of the 12 rotten/partially decomposed invertebrates decomposed to shell parts within 4.98 days (n=4, 95% C.I. 4.98-4.98), and five (38%) showed no signs of decomposition over a 7.99 day average (n=5, 95% C.I. 7.99-7.99).

Bones/Shells

There were no invertebrates originally observed in the shell parts category.

Fish

A total of 17 fish were tagged included in the decomposition studies, including three lingcod, two spotted ratfish, six spiny dogfish sharks, three kelp greenling and three fish that could not be identified due to their initial level of decomposition.

Fresh Live

Only one fish was observed as fresh live and it was completely gone within 3.02 days and had a sunflower star at its location.

Fresh Dead

Of the seven fresh dead fish observed, four (57%) were completely gone in an average of 4.45 days (n=4, 95% C.I. 4.42-4.48). Two of the four fish that were completely gone had sunflower stars at their location and were gone within 4.98 days (n=2, 95% C.I. 4.98-4.98). Three (43%) of the seven fresh dead fish decomposed to bones in an average of 12.65 days (n=3, 95% C.I. 12.17-13.13), none of which had sunflower stars at their location. No fish originally observed in a fresh dead condition remained fresh dead. All decomposed further or were completely gone from the net during the study.

Rotten/Partially Decomposed

Of the eight fish originally found in the rotten/partially decomposed category, two (25%) were completely gone within 14.98 days (n=2, 95% C.I. 14.98-14.98), and six (75%) were gone in an average of 4.31 days (n=6, 95% C.I. 4.28-4.33). None of these fish had sunflower stars at their locations.

Bones/Shells

One fish originally observed as bones remained in the same condition during a 7.02 day period.

Seabirds

Of the 33 seabirds encountered in the four derelict nets during the study, seven seabirds were encountered as rotten/partially decomposed or bones on the final dives on the nets and were not included in the decomposition analyses. Of the remaining 26 seabirds encountered, numbered tags were lost on six animals and they were also eliminated from the decomposition analyses. Of the 20 seabirds tagged for decomposition analyses two were common loons, two were grebes and 16 were cormorants. Two of the 20 seabirds were encountered as rotten/partially decomposed and 18 were encountered as bones.

Rotten/Partially Decomposed

Of the two seabirds observed in the rotten/partially decomposed condition one transitioned to bones within 2.96 days and the other remained in the same condition over a 7.94 day period (Table 5).

Bones/Shells

Of the 18 seabirds observed in the bones/shells condition, six (3%) were completely gone in an average of 14.35 days (n=6, 95% C.I. 14.10-14.60), and 12 (67%) remained in the same condition over an average period of 12.96 days (n=12, 95% C.I. 12.79-13.12) (Table 5).

Table 5. Average number of days for change in decomposition category by species group.

INVERTEBRATES	FL-FL	FL-FD	FL-R/PD	FL-B/SP	FL-CG	FD-FD	FD-R/PD	FD-B/SP	FD-CG	R/PD-R/PD	R/PD-B/SP	R/PD-CG	B/SP-B/SP	B/SP-CG
W/ & W/O Sunstars	63					25				13			0	
quantity	21	3	3	2	34	3	1	7	14	5	4	4		
% of total	33.3%	4.8%	4.8%	3.2%	54.0%	12.0%	4.0%	28.0%	56.0%	38.5%	30.8%	30.8%		
avg. days	8.00	8.28	7.51	5.12	5.43	7.96	8.00	6.73	5.96	7.99	4.98	6.71		
W/O Sunstars	47					12				11			0	
quantity	21	3	3	2	18	3	1	2	6	5	4	2		
% of total	44.7%	6.4%	6.4%	4.3%	38.3%	25.0%	8.3%	16.7%	50.0%	45.5%	36.4%	18.2%		
avg days	8.00	8.28	7.51	5.12	5.97	7.96	8.00	6.00	6.81	7.99	4.98	7.94		
Sunstars Only	16					13				2			0	
quantity					16			5	8			2		
% of total					100%			38.5%	61.5%			100%		
avg days					4.81			7.02	5.32			5.48		

ALL FISH	FL-FL	FL-FD	FL-R/PD	FL-B/SP	FL-CG	FD-FD	FD-R/PD	FD-B/SP	FD-CG	R/PD-R/PD	R/PD-B/SP	R/PD-CG	B/SP-B/SP	B/SP-CG
W/ & W/O Sunstars	1					7				8			1	
quantity					1			3	4		6	2	1	
% of total					100%			42.9%	57.1%		75.0%	25.0%	100%	
avg. days					3.02			12.65	4.45		4.31	14.98	7.02	
W/O Sunstars	0					5				8			1	
total								3	2		6	2	1	
% of total								60.0%	40.0%		75.0%	25.0%	100%	
avg days								12.65	3.92		4.31	14.98	7.02	
Sunstars Only	1					2				0			0	
quantity					1				2					
% of total					100%				100%					
avg days					3.02				4.98					

SEABIRD UNID	FL-FL	FL-FD	FL-R/PD	FL-B/SP	FL-CG	FD-FD	FD-R/PD	FD-B/SP	FD-CG	R/PD-R/PD	R/PD-B/SP	R/PD-CG	B/SP-B/SP	B/SP-CG
W/&W/O Sunstars	0					0				2			18	
quantity										1	1	0	12	6
% of total										50.0%	50.0%	0.0%	66.7%	33.3%
avg. days										7.94	2.96		12.96	14.35
W/O Sunstars	0					0				2			18	
total										1	1	0	12	6
% of total										50.0%	50.0%	0.0%	66.7%	33.3%
avg days										7.94	2.96		12.96	14.35
Sunstars Only	0					0				0			0	
quantity														
% of total														
avg days														

Key to abbreviations

FL =	Fresh Live
FD =	Fresh Dead
R/PD =	Rotten or partially decomposed
B/SP =	Bones or shell parts
CG =	Completely gone
Sunstars =	Sunflower Star (*Pycnopodia helianthoides*)

Drop-Out Rates

The dropout rate was calculated as the difference between the number of animals reported by the diver on the final dive and the number of animals observed on the deck of the vessel during net removal. Drop-out rates were calculated for each species group and physical condition category.

Fourteen of 100 invertebrates were lost during net recovery for a dropout rate of 13.9% (Table 6). Six of 19 fish were lost for a dropout rate of 31.6% and four of 19 seabirds (21.1%) were lost during final net recovery. Overall species groups 24 of 139 (17.3%) were lost during final net recovery. The dropout rate was lowest for animals in a fresh live condition (5.9%), moderate for fresh dead (14.3%) and rotten/partially decomposed (13.3%) animals and highest (33.3%) for animals in the bones/shells condition (Table 6)

Table 6: Dropout rates by species group and condition category.

	Inverts			Fish			Birds			Total		
Condition Category	Drop Outs	Total #	% Drop Out	Drop Outs	Total	% Drop Out	Drop Outs	Total	% Drop Out	Drop Outs	Total	% Drop Out
Fresh Live	3	50	6.0%	0	1	0.0%	#N/A	#N/A	#N/A	3	51	5.9%
Fresh Dead	4	26	15.4%	0	2	0.0%	#N/A	#N/A	#N/A	4	28	14.3%
Decomposed	1	12	8.3%	0	1	0.0%	1	2	50.0%	2	15	13.3%
Bones/Shells	6	13	46.2%	6	15	40.0%	3	17	17.6%	15	45	33.3%
All Conditions	14	101	13.9%	6	19	31.6%	4	19	21.1%	24	139	17.3%

Conclusion

Catch rates of invertebrates, fish and seabirds measured from the four nets indicate that derelict gillnets can continually entangle and kill animals at a fairly constant rate over long periods of time. Although the four nets studied were of dissimilar sizes, catch rates were not necessarily proportional to net size. For example, Net #4564 at Point Roberts was the smallest of the four nets studied but had one of the highest catch rates of animals (particularly invertebrates). Three of the four nets studied had been reported by commercial harvest divers six to eight months prior to removal but had likely been in place much longer. One of the four nets was originally reported by a WDFW scientist in June of 1992 and had been in place about 15 years. Assuming the derelict nets entangled animals at the average rates observed in the study, each net could be catching 92 invertebrates, 13 fish and seven seabirds each month. The derelict net off Lopez Island that had been in place for 15 years could have caught over 16,500 invertebrates, 2,340 fish and 1,260 seabirds.

Decomposition rates indicate that most animals entangled and killed in the derelict nets are decomposed within ten to 15 days. Soft-bodied animals such as fish and birds likely decompose to bones in about 5 days whereas, hard-bodied animals such as crabs may take longer to decompose and some may live entangled in the net for up to 20 days or

longer if they can obtain food and avoid being eaten by predators or scavengers. Kaiser et al. (1996) found that gadoids caught in a simulated derelict set gillnet off Wales, UK, were consumed by predators or scavengers within 72 hours after capture and divers noted a number of known local scavenger species attracted to the net. Carr et al. (1985) observed that dogfish sharks entangled in a derelict gillnet off New England attracted a variety of scavengers including starfish (*Slaster endeca*) and Caner crabs which readily consumed the entangled fish. Erzini et al. (1997) conducted a similar derelict net study of southern Portugal where divers monitored simulated derelict nets on 24 hour basis. Although divers tagged animals and recorded categories of decomposition similar to those used in this study, changes in decomposition between dive intervals were not reported. However, their 24 hours catch rates were considered underestimates of actual catch rates due to predation and scavenging of entangled animals by octopuses, cuttlefish, conger eels, moray eels and wrasses. Soft bodied animals such as red mullet (*Mullus surmuletus*) entangled and killed in the net were often completely gone within 24 hours due to scavenging.

Dropout rates calculated during the study indicate that between six and 33% of the animals entangled in the derelict nets are lost during recovery (average 17%). This indicates that counts of animals in derelict nets on the deck of the recovery vessel probably underestimate the total impact of the nets on species. The underestimate is probably higher for heavily decomposed animals recovered as bones and shells than for whole live or dead animals.

Although the study was generally successful, there were problems encountered that require further investigation. Most notably, there were an insufficient number of samples to make conclusive statements about the catch rates and decomposition of fish and seabirds. This was not the case for invertebrates, which accounted for nearly three quarters of the total animals entangled. Another issue requiring further investigation involves the decomposition of animals originally observed as Fresh Live that transitioned to Completely Gone between subsequent dive intervals. In these cases there is no way of determining whether the animal escaped, completely decomposed during the interval or was completely consumed by another animal. Considering the amount of invertebrates (crabs) that remained in a Fresh Live state during the same intervals, we may assume that specimens without sunflower stars at their location probably escaped rather than dying and decomposing completely. It is possible that they were eaten by animals other than sunflower stars, but this was not observed during any of the dive surveys. It is apparent that the presence of sunflower stars decreases the apparent decomposition rate of animals entrapped in the derelict nets. For example, two fresh dead fish, a large lingcod (est. 10 lb) and a spotted ratfish, were completely consumed by sunflower stars within five days of being observed. Bones of both fish were observed under the tag locations on the net but no part of the two fish remained entangled in the net.

In several cases, tags were not able to be observed in each interval, due to net motion from tide and wave oscillation. Monitoring nets at a higher frequency, possibly in a semi-controlled environment could potentially solve these problems in the future. Divers

may also have missed seeing some entangled animals in the nets until late in study. In several instances, seabird bones not previously tagged were found in nets on the last or next to last survey.

Decomposition of entangled animals is at times difficult to quantify. Despite the divers' best efforts, classification of an animal's physical condition can be subjective and inconsistent. The classification scheme used in this study was devised to minimize inconsistencies and was, for the most part, successful in doing such. However, the efficacy of data analysis could be increased in further studies by using a sequential number or letter scheme to classify physical condition.

The results of this study provide useful information to better determine the overall impact of derelict gillnets in Puget Sound. With preliminary catch rates, drop-out rates, and a better knowledge of the decomposition process of entangled animals, it may be possible to estimate long-term effects of derelict nets in different habitat types. With this data the impacts of previously removed derelict nets could be adjusted by adding inferred drop-outs of certain species.

Recommendations

Further research such as this would prove beneficial, especially if larger sample sizes of animals, particularly birds, fish and marine mammals can be attained. Catch, decomposition and dropout observations were not of sufficient size to analyze difference in habitat type, geographic location or net size in this study. If nets were studies for a longer period of time additional data could be collected.

In-situ studies with dead animals placed in existing derelict nets or simulated derelict nets in a semi-controlled environment could provide an opportunity to regularly observe decomposition/recycle processes without the loss of valuable information between observations.

Finally, the rate of catch and decomposition may fluctuate depending on season, giving importance to further research through repeated projects such as this one during different seasons. The study was conducted during late spring and early summer. Certain animals may be more or less abundant during other seasons and water temperature may influence decomposition rates. Predators and scavengers may also be more or less abundant during other times of the year and in particularly locations. Divers have observed that amphipods (sand fleas) rapidly infest dead animals in derelict nets off San Juan Island during the late-summer months but are not generally observed during winter months.

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