Mortality of Lingcod, *Ophiodon elongatus*, Related to Capture by Hook and Line

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Introduction

The lingcod, *Ophiodon elongatus*, is a large carnivorous fish of the family Hexagrammidae inhabiting the eastern Pacific Ocean from Alaska to Baja California (Miller and Lea, 1972). Its life cycle is entirely marine, with egg masses laid during winter on rocky habitats, typically in areas of surge or current. The male lingcod defends the nest from egg-eating fishes (Low and Beamish, 1978). Larvae and early juveniles are found in pelagic waters during the spring months, while juveniles of about 7–35 cm length inhabit nearshore sandy areas. Larger lingcod are typically found on rocky reefs at depths to 420 m (Miller and Geibel, 1973).

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ABSTRACT—Lingcod, Ophiodon elongatus, *were captured by hook and line (sport rod and reel gear and commercial troll gear) at two coastal California locations and held in aquaria for periods of up to 32 days for evaluation of capture-related mortality. Three of 69 lingcod captured with rod and reel gear died of capture-related injuries (4.3% mortality; 95% confidence interval 0–9.3%). None of 15 lingcod captured with troll gear died of capture-related injuries. Due to the low overall mortality rate, there were no discernable trends in mortality with respect to sex, length, depth of capture, and terminal tackle (bait vs. lure). Of 38 fish with visible hooking wounds, 26 showed evidence of wound healing during the holding period.*

Lingcod are taken in significant numbers by marine recreational and commercial fisheries in California (Fig. 1) and other Pacific coast states (Karpov et al., 1995; PFMC[1]). Management measures for lingcod include bag limits and minimum size limits for recreational fisheries, and catch quotas and minimum size limits for commercial fisheries. A minimum size of 56 cm (22 in) total length was applied to California's recreational fishery in 1981. In 1998 a limit of 61 cm (24 in) total length was applied to all recreational and commercial fisheries of California, Oregon, and Washington.

The portion of captured fish released live from California's recreational fishery has risen from about 10% in 1981 to about 40% in recent years (Fig. 2). Such high return rates suggested that mortality of released lingcod should be determined and, if significant, should be included in stock assessment estimates of total fishing mortality as recommended by Clark (1983).

During the past few decades, a general trend of increasing harvest pressure on fishery resources has given rise to increasing use of fishery management regulations requiring release of some (size limits) or all (catch-and-release only recreational fishing) fish captured. Additionally, many recreational anglers voluntarily return some or all fish captured as a conservation measure.

Muoneke and Childress (1994) reviewed studies, popularly called "hooking mortality" studies, evaluating mortality to fish that are hooked, landed, handled, and released. Most of the studies were conducted in fresh water and pertained to salmonids, centrarchids, or percids; mortality rates ranged from 0 to 88%.

In marine environments, Wertheimer et al. (1989) found a mortality range of 18.5–26.4% for chinook salmon, *Oncorhynchus tshawytscha*, held 4–6 days after capture by commercial trolling gear. Gjernes et al. (1993) found mortality rates of 30% for chinook salmon and 14% for coho salmon, *O. kisutch*, held less than 1 day after capture by recreational anglers. Diodati and Richards (1996) evaluated capture and release mortality of striped bass, *Morone saxatilis*, by conducting experimental angling in a 2 ha saltwater impoundment; mortality for captured fish was 9% over a 58-day period. At the end of the experiment the impoundment was drained; condition factor was significantly lower in surviving captured fish than in surviving fish that had not been captured. Bugley and Shepherd (1991) estimated capture and release mortality to black sea bass, *Centropristis striata*, by holding captured fish in wire cages on site for 48 h; mortality was 4.7%.

Ideally, the holding period in a hooking mortality study should last more than a few days because fish captured

[1] PFMC. 1996. Status of the Pacific coast groundfish fishery through 1996 and recommended acceptable biological catches for 1997: stock assessment and fishery evaluation. Pac. Fish. Manage. Counc. 2130 S.W. Fifth Ave., Suite 224, Portland, OR 97201.

and released in apparently good condition can expire days later. Delayed mortality can occur from hooking wounds, disease, or osmoregulatory dysfunction (Muoneke and Childress, 1994).

Methods

Our general approach was to capture lingcod using traditional hook and line gear and then hold them in aquaria as long as practical to observe their general condition and the condition of any wounds arising from capture. When a fish became ill or died, we attempted to attribute the illness or death to either a) physical injuries and stress incurred during capture or b) injuries and stress incurred as a result of holding the fish for evaluation.

Monterey County

During 24–29 September 1995, 15 lingcod were captured and held aboard the California Department of Fish and Game vessel RV *Mako* off Monterey County (Fig. 3). Using sonar, schools of fish were located over rocky habitats at depths <50 m. The vessel was then drifted over the schools, and anglers fished with conventional recreational rod and reel gear, mainly with large baits or lures intended to target lingcod. Baits were predominately live market squid, *Loligo opalescens*; live jack mackerel, *Trachurus symmetricus*; or live Pacific sardine, *Sardinops sagax*. All hooks had a typical single barb on the point. Nearly all hooks had a gap distance from the point to the shank of 18–20 mm and were single hooks; however, some anglers occasionally used somewhat larger or smaller hooks or treble hooks.

To enable identification of individual fish during the holding period, captured lingcod were tagged with model FD-94 numbered yellow anchor tags[2] anchored in the dorsal musculature between proximal pterygiophores. Fork length, sex (based on external genitalia), depth of capture, and terminal tackle (bait or lure) were recorded. Tackles with bait attached to a lure were recorded as bait.

Lingcod surviving immediate capture were placed in an onboard flow-through live well measuring $1.5 \times 1.5 \times 2$ m. A habitat structure consisting of nine 102 mm diameter plastic pipes about 0.7 m long, bundled together, was placed in the live well to give the lingcod an opportunity to stabilize themselves within crevice-like locations and isolate themselves from one another. Lingcod in the live well were evaluated daily for condition and mortality and fed small live rockfish (*Sebastes* spp.) and other live baits to satiation in order to provide nutrition and discourage cannibalism.

On 29 September, 10 of the surviving lingcod and the habitat structure were transferred to Monterey Bay Aquarium where they were held in a $1.2 \times 1.2 \times 1.2$ m continuous flow aquarium 18 days for further observation. Daily, they were evaluated and fed dead market squid to satiation.

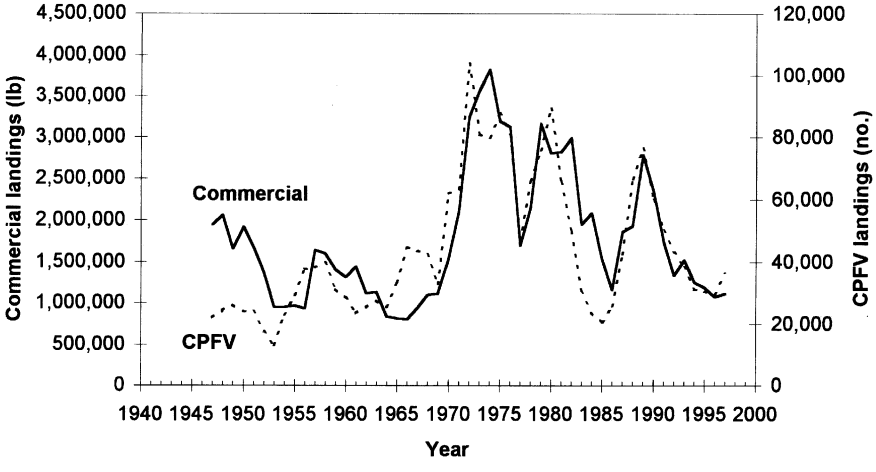

Figure 1.—California lingcod catch by commercial fisheries (California Department of Fish and Game landing receipt data) and commercial passenger fishing vessels (CPFV) (California Department of Fish and Game vessel log data).

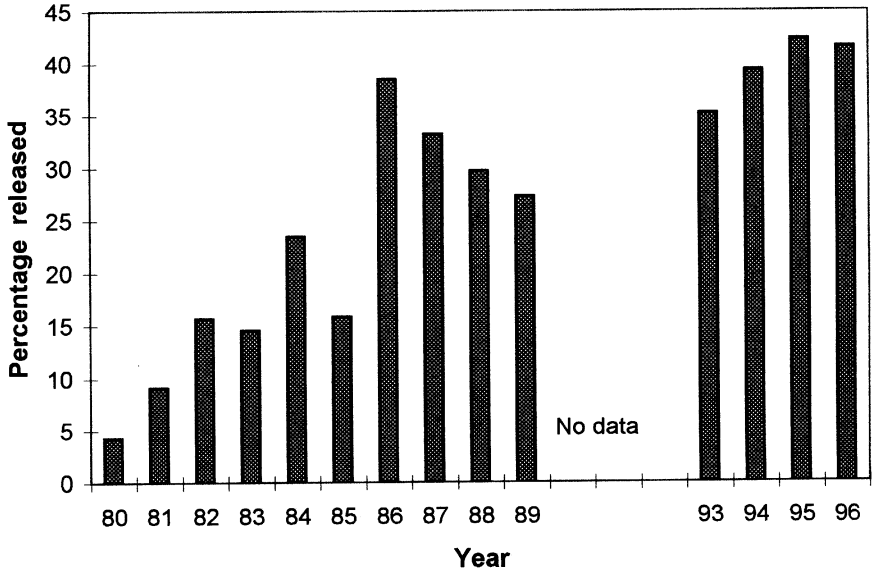

Figure 2.—Percent of California's recreational lingcod catch released alive (Pacific States Marine Fisheries Commission RecFIN data).

[2] Floy Tag and Manufacturing Inc., Seattle, Wash. Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Mendocino County

During January–August 1996, 69 lingcod were captured from Mendocino County waters (Fig. 3) from Department of Fish and Game vessels and chartered commercial fishing vessels. The lingcod were captured as part of a multipurpose nearshore reef fish tagging study. Again, sonar was employed to locate aggregations of fish over rocky habitats. Since a main purpose of the fishing was to capture rockfish for tagging and release with minimal injury, depths fished were usually less than 30 m, and bait was seldom used. Lingcod >61 cm total length were generally not retained because mortality to fish near or below the minimum size limit was of greatest interest. Rod and reel was the gear used on the multipurpose reef fish tagging trips. However, trolling gear was also used on two special trips targeting lingcod to evaluate mortality resulting from that gear and also to evaluate mortality of fish caught from depths >30 m.

The Mendocino County lingcod were tagged with dorsal anchor tags, like the Monterey County fish, or with 5 × 17 mm oval disk tags[2] attached to the opercular bone with fabric basting tacks.[3] Gear, depth of capture, hook location, fork length, and sex were recorded. The fish were held in onboard flow-through live wells and transported to the Fort Bragg High School Marine Laboratory at the end of the day. At the laboratory, the lingcod were segregated by size into different 1,000 l aquaria to minimize predation. Bundled plastic pipes were placed in the aquaria to provide habitat structure. Three times per week, the lingcod were observed and fed dead market squid or anchovy, *Engraulis mordax*, to satiation.

In both Monterey and Mendocino counties, the anglers (mainly Department of Fish and Game biologists or commercial fishermen) were instructed to handle the lingcod with the same care they would if they were recreational fishing. Some individuals wore rubber gloves to handle the fish, but most did not. The fish were not anesthetized for handling, so fish occasionally squirmed free and landed on the deck.

[3] Quiltak Inc., Flagstaff, Ariz.

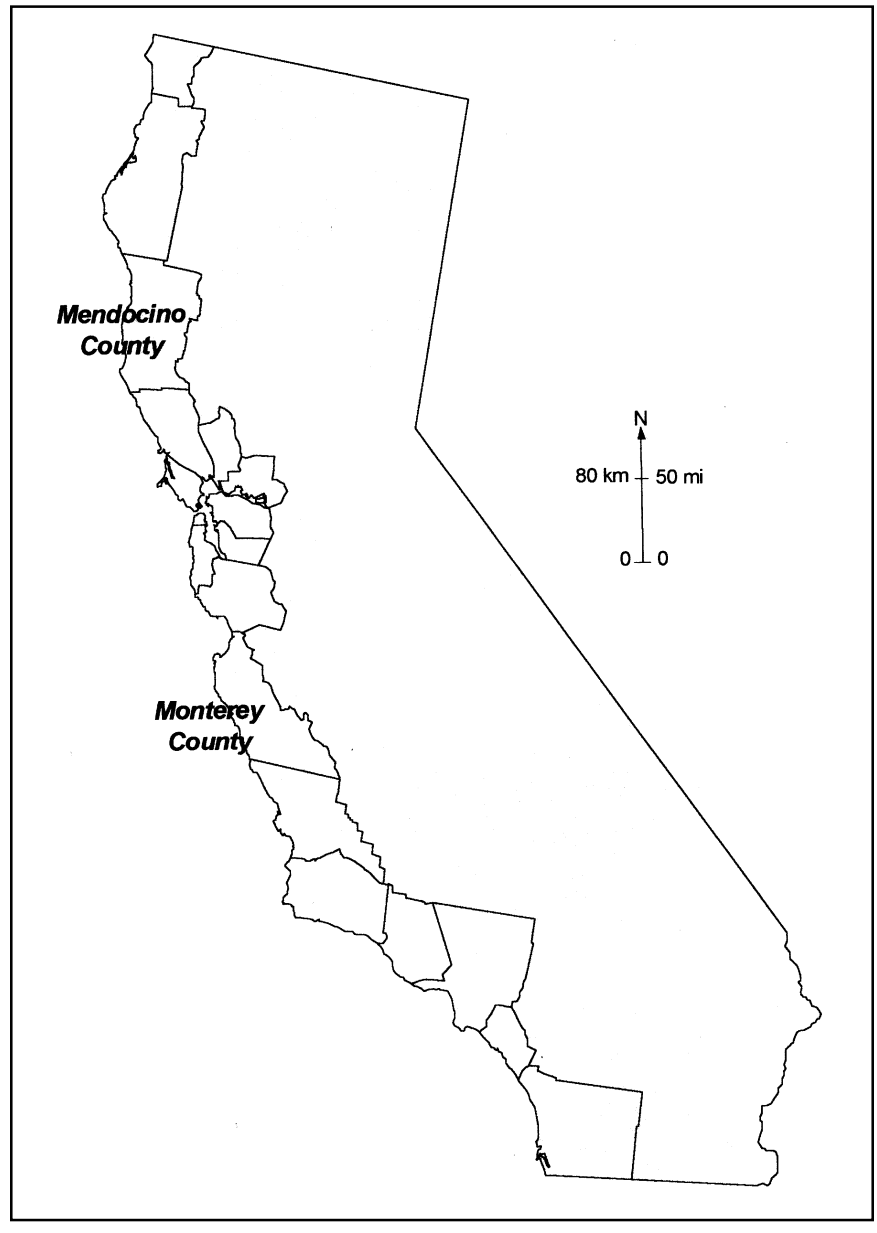

Figure 3.—Mendocino and Monterey counties, Calif.

The holding period for fish that survived immediate hooking and landing ranged from 2–32 days ($\bar{x}$ = 15 days). At the end of the holding period, surviving lingcod were given a final examination and released to the ocean.

Results

Of the 84 lingcod captured, 65 were males, 17 were females, and the sex of two was not determined (Table 1). Fork length of males ranged from 355 to 686 mm; fork length of females ranged from 279 to 670 mm (Fig. 4). Capture depths ranged from 6 to 64 m.

Three fish died during the holding period (Table 1). Of those three, one died of causes clearly attributable to capture. That fish, number 7, suffered a puncture wound to the ventral aorta when it was hooked and bled to death on landing. Another fish, number 60, died while being transported to the Fort Bragg High School Marine Laboratory,

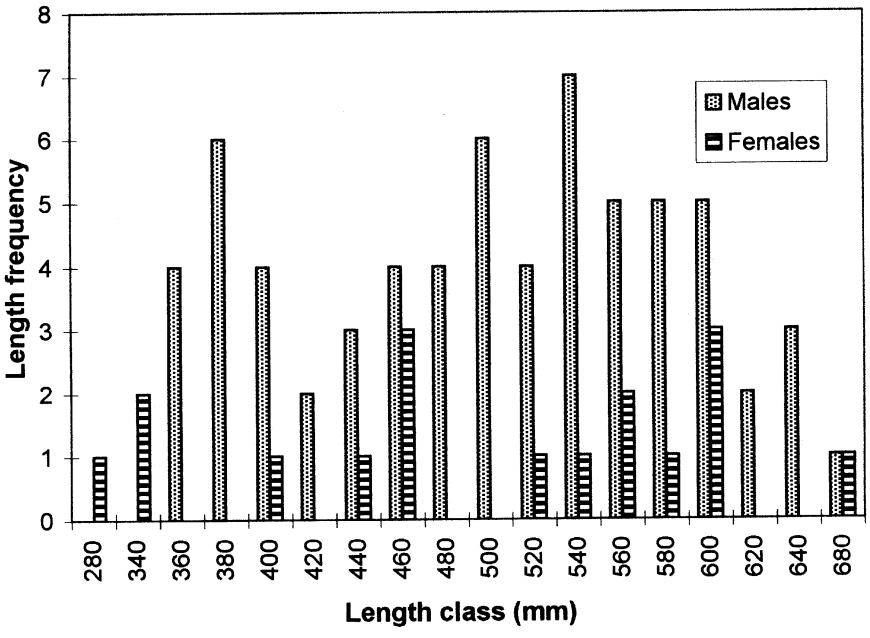

Figure 4.—Sex and length frequency composition of captured lingcod.

and another, number 48, died while being transported back to the ocean for release.

Fish number 43 survived the holding period but was very lethargic on release. It had developed an infection in the eye region where it had been punctured by the hook when captured. We assume fish number 43 did not survive long following release, and we attribute its death to injuries sustained during capture.

The deaths of fish numbers 48 and 60 were not attributable to any apparent physical injuries, and were probably due to physiological stress from being handled. Since fish 48 died 4 days after its capture and was handled shortly before death, we do not attribute its death to handling stress incurred during capture. Fish 60 died about 6 h after it was captured. Handling stress from capture probably contributed to its death because stress-induced blood parameter changes in fish can remain at least 6 h (Novak[4]). At 279 mm fork length, it was the smallest lingcod captured in the study. We conclude that, of the 84 fish captured, capture-related injuries caused the death of three fish (numbers 7, 43, and 60); cause was generally not difficult to discern.

All three of the capture-related mortalities were captured with rod and reel gear. The mortality rate for rod and reel gear is therefore 3/69 = 4.3%. For the binomial mortality rate (p), the variance (v) can be computed as

$$v = pq/n,$$

where $q = 1\text{-}p$ and n is the sample size (Sokal and Rohlf, 1969). Assuming a normal approximation to the binomial distribution, the 95% confidence interval for the rod and reel mortality rate is 0–9.3%. None of the 15 lingcod captured with troll gear died of capture-related injuries.

Discussion

Due to the low overall mortality rate relative to the sample size, it is not possible to statistically isolate the effects of capture depth, terminal tackle, fish length, and sex on mortality. Much larger sample sizes would be needed to study those factors.

The three fish that died due to capture-related injuries were taken from a range of depths (6, 20, and 27 m). Fish were brought up from depths as great as 64 m with no signs of barotrauma (e.g. gas bubbles in the eyes). Lingcod lack a swim bladder and apparently do not suffer adverse gas expansion effects.

Fork lengths of the three capture-related mortalities were 279, 337, and 627 mm, an indication that smaller lingcod might prove to be more sensitive to capture-related mortality given a larger sample size. We noted capture-related wounds, typically hook punctures in the mouth area, in 38 of the fish held. In 26 of the 38 we observed evidence of healing (e.g. cessation of bleeding, smaller wound diameter) during the holding period. Wounds observed not healing were typically tears in poorly vascularized membranous tissues around the mouth.

Conclusions

Lingcod generally tolerated capture and handling well despite decompression, handling with nets and bare hands, and occasionally being dropped on the deck. Delayed mortality did not prove to be of significant concern. These results support the reputation of lingcod as a relatively hardy species and the use of a minimum size limit as a management tool.

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[4] K. Novak, D.V.M. 1996. Fish veterinarian, 700 N. Franklin St., Fort Bragg, CA 95437. Personal commun.

Table 1.—Lingcod captured by hook and line gears and held for mortality observations.

Fish no.	Capture date	Capture gear	Terminal tackle	Capture depth (m)	Fork length (mm)	Sex	Days held	Capture-related mortality	Holding-related mortality	Wounds observed healing
1	9/24/95	Rod & reel	Bait	18	508	M	6			
2	9/24/95	Rod & reel	Lure	27	503	M	23			Yes
3	9/24/95	Rod & reel	Bait	23	602	M	6			Yes
4	9/25/95	Rod & reel	Bait	37	598	F	22			Yes
5	9/25/95	Rod & reel	Lure	37	416	M	22			Yes
6	9/26/95	Rod & reel	Lure	20	521	M	21			No
7	9/26/95	Rod & reel	Lure	27	337		0	X		
8	9/26/95	Rod & reel	Bait	27	453		21			Yes
9	9/26/95	Rod & reel	Lure	9	670	F	21			No
10	9/27/95	Rod & reel	Bait	27	435	M	20			No
11	9/27/95	Rod & reel	Bait	23	630	M	3			
12	9/27/95	Rod & reel	Lure	21	600	M	20			Yes
13	9/28/95	Rod & reel	Bait	23	568	M	2			
14	9/28/95	Rod & reel	Bait	23	572	M	19			No
15	9/28/95	Rod & reel	Lure	47	603	F	19			No
16	1/11/96	Rod & reel	Lure	14	462	M	18			
17	1/11/96	Rod & reel	Lure	14	490	M	18			
18	1/11/96	Rod & reel	Lure	14	446	F	18			
19	1/11/96	Rod & reel	Lure	14	544	M	18			
20	1/11/96	Rod & reel	Lure	14	686	M	18			
21	3/1/96	Rod & reel	Lure	13	597	M	27			No
22	3/1/96	Rod & reel	Lure	13	609	M	27			
23	3/1/96	Rod & reel	Lure	13	430	M	27			
24	3/1/96	Rod & reel	Lure	13	509	M	27			Yes
25	3/1/96	Rod & reel	Lure	13	636	M	27			
26	4/5/96	Rod & reel	Lure	13	345	F	20			No
27	4/5/96	Rod & reel	Lure	13	428	M	20			
28	5/6/96	Rod & reel	Lure	27	383	M	15			
29	5/6/96	Rod & reel	Lure	27	355	M	15			
30	5/6/96	Rod & reel	Lure	27	372	M	15			
31	5/6/96	Rod & reel	Lure	27	367	M	15			
32	5/6/96	Rod & reel	Lure	27	378	M	15			
33	5/6/96	Rod & reel	Lure	27	365	M	15			
34	5/6/96	Rod & reel	Lure	27	357	M	15			Yes
35	5/6/96	Rod & reel	Lure	27	514	M	15			
36	5/6/96	Rod & reel	Lure	27	447	M	15			
37	5/6/96	Rod & reel	Lure	27	530	M	15			Yes
38	6/27/96	Rod & reel	Lure	7	498	M	4			
39	6/27/96	Rod & reel	Lure	7	375	M	4			
40	6/27/96	Rod & reel	Lure	8	464	M	4			
41	6/24/96	Rod & reel	Lure	10	484	M	7			
42	6/24/96	Rod & reel	Lure	10	488	M	7			
43	6/19/96	Rod & reel	Lure	6	627	M	12	X		No
44	6/20/96	Rod & reel	Lure	20	378	M	11			Yes
45	6/20/96	Rod & reel	Lure	20	455	F	11			
46	6/19/96	Rod & reel	Lure	6	549	M	12			
47	6/19/96	Rod & reel	Lure	6	543	M	12			
48	6/27/96	Rod & reel	Lure	7	568	M	4		X	
49	6/19/96	Rod & reel	Lure	6	545	M	12			
50	8/5/96	Rod & reel	Lure	18	408	M	11			
51	8/5/96	Rod & reel	Lure	16	481	M	11			Yes
52	8/5/96	Rod & reel	Lure	16	507	M	11			
53	7/30/96	Rod & reel	Lure	20	402	F	17			
54	7/30/96	Rod & reel	Lure	20	589	M	17			
55	7/30/96	Rod & reel	Lure	20	589	F	17			
56	7/30/96	Rod & reel	Lure	20	459	F	17			
57	7/30/96	Rod & reel	Lure	20	408	M	17			
58	7/30/96	Rod & reel	Lure	10	465	M	17			
59	7/30/96	Rod & reel	Lure	12	456	M	17			
60	7/30/96	Rod & reel	Lure	20	279	F	0	X		
61	8/21/96	Bar troll	Lure	40	538	M	9			Yes
62	8/22/96	Bar troll	Lure	55	519	M	8			Yes
63	8/22/96	Bar troll	Lure	55	568	M	8			Yes
64	8/22/96	Bar troll	Lure	55	575	M	8			Yes
65	8/22/96	Bar troll	Lure	55	570	M	8			Yes
66	8/22/96	Bar troll	Lure	55	550	F	8			Yes
67	8/22/96	Bar troll	Lure	55	459	F	8			Yes
68	8/22/96	Bar troll	Lure	55	554	M	8			Yes
69	8/22/96	Bar troll	Lure	55	567	M	8			No
70	8/22/96	Bar troll	Lure	55	608	M	8			Yes
71	8/22/96	Bar troll	Lure	55	595	F	8			Yes
72	8/22/96	Bar troll	Lure	55	480	M	8			Yes
73	8/22/96	Bar troll	Lure	55	549	F	8			Yes
74	8/21/96	Bar troll	Lure	64	525	F	9			No
75	8/21/96	Bar troll	Lure	40	540	M	9			Yes
76	8/14/96	Rod & reel	Lure	15	378	M	16			Yes
77	9/19/96	Rod & reel	Lure	26	556	F	32			
78	9/25/96	Rod & reel	Bait	9	588	M	26			
79	9/27/96	Rod & reel	Lure	13	519	M	24			No
80	9/27/96	Rod & reel	Lure	13	611	M	24			
81	9/27/96	Rod & reel	Lure	13	639	M	24			Yes
82	9/27/96	Rod & reel	Lure	13	397	M	24			
83	9/27/96	Rod & reel	Lure	13	400	M	24			No
84	9/27/96	Rod & reel	Lure	13	333	F	24			

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