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ADMINISTRATIVE REPORT LJ-99-07C

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Abstract

The *R/V Endeavor* was equipped with a towed array of hydrophones and a pair of hull-mounted hydrophones for the purpose of recording delphinid vocalizations during the 1998 *Stenella* Population Abundance Monitoring (SPAM) cruise in the Eastern Tropical Pacific Ocean (ETP). Typical whistle contour types and burst pulse vocalizations are presented for nine of the species successfully recorded in the ETP: bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*), offshore pantropical spotted dolphin (*S. attenuata*), short-beaked common dolphin (*Delphinus delphis*), long-beaked common dolphin (*D. capensis*), rough-toothed dolphin (*Steno bredanensis*), dusky dolphin (*Lagenorhynchus obscurus*), short-finned pilot whale (*Globicephala macrorhynchus*), unidentified pilot whale (*Globicephala spp.*), and false killer whale (*Pseudorca crassidens*). A preliminary aural and visual examination of these vocalizations suggests that there may be significant inter-species differences in delphinid whistle structure. The ability to acoustically identify cetacean species and stocks of species could be of great value on line transect surveys, aiding visual observers in species identification and helping to better define currently recognized stocks.

Introduction

Yellowfin tuna (*Thunnus albacares*) are often found in association with spinner (*Stenella longirostris*), spotted (*Stenella attenuata*), and common (*Delphinus delphis*) dolphins in the Eastern Tropical Pacific ocean (ETP) (Joseph 1994). The ETP yellowfin tuna fishery is one of the most important in the world, and it has been estimated that approximately 53,000 – 129,000 dolphins were killed annually as a result of commercial purse-seine tuna fishing operations between 1985 and 1990 (Perrin *et al.* 1994). Since 1992, annual mortality has dropped to a few thousand dolphins per year (Lennert and Hall 1995, 1996). This drastic reduction in incidental take is a result of a number of measures, including U.S. embargoes and limitations set on U.S. vessels with respect to the number of dolphins that may be killed (Perrin *et al.* 1994, Joseph 1994).

In order to determine whether the reduced dolphin mortality is leading to population increases, the Southwest Fisheries Science Center (SWFSC) has planned a series of three surveys to generate new estimates of dolphin abundance in the ETP. The first "*Stenella* Population Abundance Monitoring" (SPAM) survey occurred during the fall months of 1998, and subsequent surveys will take place in 1999 and 2000. SPAM surveys follow line transect methods similar to those used during the 1986-90 Monitoring of Porpoise Stocks (MOPS) surveys (Wade and Gerrodette 1992). Population estimates will be made for the dolphin populations most affected by the tuna purse-seine fishery: coastal spotted dolphins (*Stenella attenuata graffmani*), northeastern offshore spotted dolphins, western/southern offshore spotted dolphins (*S. attenuata attenuata*), and eastern spinner dolphins (*S. longirostris orientalis*) (Olson and Gerrodette 1999).

The 1998 SPAM survey provided a unique opportunity to make acoustic recordings of many cetacean species. One of the three research vessels involved in the survey, the *R/V Endeavor*, was equipped with a towed array of hydrophones as well as a pair of hull-mounted hydrophones.

The primary objective of towing a hydrophone array during the SPAM 1998 cruise was to determine whether acoustic information has the potential to significantly aid in the estimation of dolphin abundance. Line transect surveys depend on visual sightings of animals, however cetaceans spend a large amount of their time out of sight underwater and sighting conditions at sea vary greatly. These factors could result in a violation of the assumption that all animals on a transect line are seen, and thus adversely affect population size estimates (Thomas *et al.* 1986). Many cetaceans are extremely vocal, and since underwater sounds can be received over large distances, acoustic surveys are possibly a supplemental method for detecting and identifying cetaceans. The addition of acoustics to visual surveys could enhance the accuracy of visual counts, and thus population size estimates. In order to examine the possible benefits of using a towed array in line-transect surveys of marine mammals, questions such as: "are dolphin groups missed by visual observers detected acoustically ?", "where are acoustically detected dolphins located relative to the ship?", and "under what conditions are dolphin schools detected acoustically and missed visually?" must be answered. These questions will be addressed in later analyses of data collected on the SPAM 1998 cruise.

A large number of cetacean species were recorded from the towed hydrophone array and several species from the hull mounted hydrophones. This report will discuss the methods used to record cetacean vocalizations on the SPAM 1998 survey, and will present a preliminary library of representative vocalizations recorded from nine delphinid species in the ETP. Finally, recommendations for future research will be discussed.

Materials and Methods

Study area

The *R/V Endeavor*, a 185ft oceanic research vessel from the University of Rhode Island surveyed 14,279 nautical miles of trackline between July 30 and December 9, 1998[1]. The cruise was divided into five legs with four to five day port calls between each leg. The study area extended from the U.S./Mexico border in the north to the territorial waters of Peru in the south. It was bounded on the east by the continental shores of the Americas and extended west to Hawaii. The hydrophone array was towed for 8,580 nautical miles in the international waters of the ETP and in the coastal waters of Mexico, Costa Rica, Panama, Ecuador, Columbia, and Peru (Fig. 1)[2].

Hydrophone Arrays

The primary towed array ("Norris" array) was built by Don Norris of SonaTech, Inc. It was a three element array with a frequency range of 500Hz to 150kHz. Relative element distances were 0, 5, and 9 meters. This array was used on legs 1, 3, 4, and 5 (it was damaged at the end of leg 1 and was sent back to San Diego for repair during leg 2).

A secondary array (ITI array) was built by Innovative Transducers, Inc. It was a five element array with a frequency range of 10Hz – 20kHz, although it had a gentle roll-off above 6kHz. Relative element distances were 0, 1, 3, 7, and 15 meters. This array replaced the Norris array while the latter was in San Diego for repairs during leg 2.

The towed array was deployed from the stern of the vessel using a hydraulic winch each morning prior to commencement of marine mammal watches. It was retrieved each evening after marine mammal observations had ended. The array was also retrieved for small vessel operations and for 90 minute sperm whale group size estimation periods.

[1,2] Kinzey, D., P. Olson, T. Gerodette, and R. Brownell. 1999. Final Cruise Report, UNOLS Ship Endeavor. Southwest Fisheries Science Center, National Marine Fisheries Service. La Jolla, CA. 13pp.

The array was towed 200m behind the ship, a distance which did not interfere significantly with marine mammal chases. Vessel speed was limited to 10 knots in order to avoid exceeding the safe working load of the tow cable, and vessel turn angle was limited to approximately 3° degrees rudder angle to avoid running over the tail of the array.

Power was supplied to the arrays by a pair of 12v car batteries. Acoustic signals were amplified (100X) and filtered (2 – 20kHz) on-board the ship. Amplifiers and filter boxes were powered by a separate, smaller pair of 12v batteries.

Hull Mounted Hydrophones

The two hull mounted hydrophones had a frequency response of 500Hz to 200kHz. Frequencies less than approximately 5kHz were masked by ship noise. Whistles and clicks emitted by bow-riding dolphins and other dolphins within 100m of the ship were picked up by the hull mounted hydrophones and digitally recorded directly to the hard drive of a Dell computer. Signals were amplified (10x) and filtered (1-150kHz) prior to recording.

Computer Hardware

Two hydrophones in the towed array were aurally monitored simultaneously by an acoustic technician, and a Dolch 586 lunch-box-style computer was used to continuously produce a scrolling spectrogram from the forward hydrophone. The Dolch contained a 100MHz Pentium CPU, 2GB SCSI hard drive, and a Data Translation DT-3809 DSP board. It had the capability to continuously digitize and record acoustic signals to its hard drive at a rate of 400,000 12-bit samples per second.

A 200MHz Dell Pentium computer continuously ran the data collection program "WhalTrak" while on acoustic effort, and was also used to record broadband signals from the hull-mounted hydrophones. The Dell computer was equipped with a Data Translation DT-3809 DSP board, and was capable of continuously writing to the hard disk at a sustained maximum rate of 285,000 12-bit samples per second.

Digital Audio Tape Recorder

Most cetacean vocalizations were recorded onto Digital Audio Tape (DAT) using a Sony TCD-D7 DAT walkman. The DAT walkman was able to record frequencies up to 22kHz. Recordings were made of clear, high signal-to-noise (S/N) vocalizations, and data such as date, time, location, species identification, vocalization type, and ambient noise level were entered into "WhaleTrak" and Microsoft Excel spreadsheets.

Spectrograms

Approximately four to eight hours of DAT recordings were made on each leg of the cruise. For this report, a subset of eight hours of these DAT recordings were analyzed. Segments of tape containing clear, easily heard vocalizations with little ship and other ambient noise were digitized onto a Pentium 133 computer using the sound analysis programs "Spectrogram" and "CoolEdit". Digitized samples were examined and examples of typical whistle contour types and burst pulse vocalizations were chosen to be included in this report. Only vocalizations with high S/N ratios and little overlap with other vocalizations have been included.

Segments were only digitized if the animals recorded had been seen and identified to species by experienced marine mammal observers. Groups of animals that contained more than one species were excluded from this analysis. While every effort was made to analyze only single species recordings, it is possible that recordings were contaminated by the presence of multiple, unobserved species within or nearby groups labeled "single species".

Results

Vocalizations of the following species are presented in Figures 2-39: bottlenose dolphin (*Tursiops truncatus*), striped dolphin *(Stenella coeruleoalba*), offshore pantropical spotted dolphin (*S. attenuata*), short-beaked common dolphin (*Delphinus delphis*), long-beaked common dolphin (*D. capensis*), rough-toothed dolphin (*Steno bredanensis*), dusky dolphin (*Lagenorhynchus obscurus*), short-finned pilot whale (*Globicephala macrorhynchus*), unidentified pilot whale (*Globicephala spp.*), and false killer whale (*Pseudorca crassidens*). Sighting number, date, location, and group size estimate are given for each spectrogram in Table 1.

Discussion

A preliminary aural and visual examination of a subset of data collected on the SPAM 1998 cruise suggests that there may be significant inter-species differences in delphinid whistle structure. This speculation is supported by the work of Ding (1993), who found significant differences in the whistle structures of seven dolphin species: dusky dolphins, Hawaiian spinner dolphins, Atlantic spotted dolphins (*Stenella frontalis*), pantropical spotted dolphins, tucuxi (*Sotalia fluviatilis*), Amazon river dolphins or boto (*Inia geoffrensis*), and bottlenose dolphins. Steiner (1981) found significant differences in the whistle contours of five dolphin species: bottlenose dolphins, long-finned pilot whales (*G. melaena*), Atlantic white-sided dolphins (*L. acutus*), Atlantic spotted dolphins, and spinner dolphins. Both Ding (1993) and Steiner (1981) found that relative degrees of species distinctiveness were related to taxonomic relations, body sizes, and habitats. In general, the more distantly two species were related, the greater were the differences between their whistles. Larger dolphins generally had lower frequency whistles than smaller dolphins, and pelagic species had higher frequency ranges and more frequency modulation than coastal species.

The ability to acoustically identify cetacean species could be of great value on line transect surveys. Thomas *et al.* (1986) were able to audibly identify eight cetacean species from their acoustic signatures: sperm whales, pilot whales, false killer whales, spotted dolphins, spinner dolphins, common dolphins, Risso's dolphins (*Grampus griseus*), and striped dolphins. In some cases they were also able to audibly identify whether a school was homogeneous or mixed. In a situation like that described by Thomas *et al.* (1986), an acoustic team would be able to help visual observers identify sightings, a task that can be difficult, especially in bad weather conditions or with elusive groups of animals. It is also important to identify which species are heard and not seen in order to determine whether this is a species specific characteristic.

In addition to acoustically identifying species, Thomas *et al.* (1986) were, in some cases, able to distinguish different stocks of the same species. The ability to acoustically distinguish stocks could help better define currently recognized stocks, such as the coastal, northeastern offshore, and western/southern offshore stocks of spotted dolphins. A clear definition of stocks is especially important in the ETP where each stock is assigned a quota for maximum allowable incidental mortality associated with tuna purse seine fishing (Hohn and Benson 1990). A concerted effort should be made to collect and analyze whistles from each stock of spotted, spinner and common dolphin in the ETP.

When collecting additional acoustic data, a greater number of broadband recordings should be made. The fundamental frequencies of the whistles of some species presented in this report (striped, spotted, common, and bottlenose dolphins) reached beyond the 22kHz recording capacity of the DAT recorder, and important characteristics of these whistles could be missed by not examining them in their entirety. These characteristics could prove to be important when attempting to acoustically distinguish species and stocks.

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Table 1. Date, sighting number, location, and school size estimate for spectrograms presented in Figures 2 - 39. The hydrophones used to make each recording are given in the last column. School size estimates are the means of the best estimates of marine mammal observers.

BITMAP FILENAME	DATE	SIGHTING NUMBER	LATITUDE	LONGITUDE	SCHOOL SIZE	HYDROPHONES USED
Tursiops truncatus						
52turs32a	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
52turs34a	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
52turs38c	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
52turs10b	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
52turs10a	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
52turs311a	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
52turs311b	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
52turs311c	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
52turs313a	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
52turs314a	10/22/98	369	N 10:11.88	W 089:18.08	64	Norris
Stenella coeruleoalba						
52striped11a	10/22/98	366	N 10:07.84	W 089:24.41	33	Norris
52striped11b	10/22/98	366	N 10:07.84	W 089:24.41	33	Norris
52striped11c	10/22/98	366	N 10:07.84	W 089:24.41	33	Norris
56striped51a	11/6/98	437	S 08:22.19	W 097:01.80	112	Norris
56striped52a	11/6/98	437	S 08:22.19	W 097:01.80	112	Norris
56striped52b	11/6/98	437	S 08:22.19	W 097:01.80	112	Norris
56striped61a	11/6/98	437	S 08:22.19	W 097:01.80	112	Norris
56striped61c	11/6/98	437	S 08:22.19	W 097:01.80	112	Norris
56striped71c	11/6/98	438	S 08:26.98	W 097:10.90	32	Norris
56striped71e	11/6/98	438	S 08:26.98	W 097:10.90	32	Norris
56striped71g	11/6/98	438	S 08:26.98	W 097:10.90	32	Norris
56striped73a	11/6/98	438	S 08:26.98	W 097:10.90	32	Norris
56striped73b	11/6/98	438	S 08:26.98	W 097:10.90	32	Norris
Stenella attenuata						
52spot41a	10/22/98	371	N 10:15.49	W 089:12.63	72	Norris
52spot42a	10/22/98	371	N 10:15.49	W 089:12.63	72	Norris
52spot42c	10/22/98	371	N 10:15.49	W 089:12.63	72	Norris
52spot42e	10/22/98	371	N 10:15.49	W 089:12.63	72	Norris
52spot43a	10/22/98	371	N 10:15.49	W 089:12.63	72	Norris
52spot43b	10/22/98	371	N 10:15.49	W 089:12.63	72	Norris
52spot71b	10/22/98	377	N 09:58.96	W 088:59.09	34	Norris
52spot72a	10/22/98	377	N 09:58.97	W 088:59.09	34	Norris
52spot73a	10/22/98	377	N 09:58.98	W 088:59.09	34	Norris

Table 1 continued.

BITMAP FILENAME	DATE	SIGHTING NUMBER	LATITUDE	LONGITUDE	SCHOOL SIZE	HYDROPHONES USED
Delphinus delphis						
52delph61c	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph66a	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph67a	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph67b	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph68a	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph68b	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph68c	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph69a	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph610a	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph612a	10/22/98	375	N 10:01.33	W 089:00.91	150	Norris
52delph91b	10/22/98	381	N 09:58.58	W 088:28.59	128	Norris
52delph91c	10/22/98	381	N 09:58.58	W 088:28.59	128	Norris
52delph97a	10/22/98	381	N 09:58.58	W 088:28.59	128	Norris
Delphinus capensis						
58capensis101a	11/22/98	483	S 10:33.96	W 078:10.08	383	Norris
58capensis101b	11/22/98	483	S 10:33.96	W 078:10.08	383	Norris
58capensis102a	11/22/98	483	S 10:33.96	W 078:10.08	383	Norris
58capensis102c	11/22/98	483	S 10:33.96	W 078:10.08	383	Norris
58capensis103b	11/22/98	483	S 10:33.96	W 078:10.08	383	Norris
58capensis104a	11/22/98	483	S 10:33.96	W 078:10.08	383	Norris
58capensis104c	11/22/98	483	S 10:33.96	W 078:10.08	383	Norris
58capensis108a	11/22/98	483	S 10:33.96	W 078:10.08	383	Norris
58capensis111a	11/22/98	484	S 10:32.61	W 078:24.58	420	Norris
58capensis112a	11/22/98	484	S 10:32.61	W 078:24.58	420	Norris
58capensis113a	11/22/98	484	S 10:32.61	W 078:24.58	420	Norris
58capensis114a	11/22/98	484	S 10:32.61	W 078:24.58	420	Norris
58capensis114b	11/22/98	484	S 10:32.61	W 078:24.58	420	Norris
Steno bredanensis						
44steno62a	8/26/98	126	N 19:40.19	W 156:10.72	14	Norris
44steno63a	8/26/98	126	N 19:40.19	W 156:10.72	14	Norris
44steno63b	8/26/98	126	N 19:40.19	W 156:10.72	14	Norris
44steno66a	8/26/98	126	N 19:40.19	W 156:10.72	14	Norris
44steno67a	8/26/98	126	N 19:40.19	W 156:10.72	14	Norris
44steno69a	8/26/98	126	N 19:40.19	W 156:10.72	14	Norris
44steno610a	8/26/98	126	N 19:40.19	W 156:10.72	14	Norris
44steno611a	8/26/98	126	N 19:40.19	W 156:10.72	14	Norris
44steno612a	8/26/98	126	N 19:40.19	W 156:10.72	14	Norris

Table 1 continued.

BITMAP FILENAME	DATE	SIGHTING NUMBER	LATITUDE	LONGITUDE	SCHOOL SIZE	HYDROPHONES USED
Lagenorhynchus obscurus						
58dusky15b	11/21/98	468	S 11:54.27	W 077:28.34	284	Norris
58dusky16b	11/21/98	468	S 11:54.27	W 077:28.34	284	Norris
58dusky19a	11/21/98	468	S 11:54.27	W 077:28.34	284	Norris
58dusky110a	11/21/98	468	S 11:54.27	W 077:28.34	284	Norris
58dusky21a	11/21/98	472	S 11:50.24	W 077:36.81	56	Norris
58dusky23a	11/21/98	472	S 11:50.24	W 077:36.81	56	Norris
58dusky213a	11/21/98	472	S 11:50.24	W 077:36.81	56	Norris
58dusky212a	11/21/98	472	S 11:50.24	W 077:36.81	56	Norris
58dusky211a	11/21/98	472	S 11:50.24	W 077:36.81	56	Norris
58dusky211b	11/21/98	472	S 11:50.24	W 077:36.81	56	Norris
58dusky210a	11/21/98	472	S 11:50.24	W 077:36.81	56	Norris
Globicephala macrorhynchus						
44pilot51a	8/26/98	120	N 19:20.19	W 156:04.65	22	Norris
44pilot41a	8/26/98	118	N 19:01.03	W 155:57.27	156	Norris
44pilot41b	8/26/98	118	N 19:01.03	W 155:57.27	156	Norris
pilot6w1	8/26/98	128	N 19:19.01	W 156:06.67	8	Hull-mounted
gm30dat	9/17/98	187	N 12:34.83	W 124:05.20	40	ITI
gm33dat	9/17/98	187	N 12:34.83	W 124:05.20	40	ITI
gm36dat	9/17/98	187	N 12:34.83	W 124:05.20	40	ITI
Globicephala species						
44pilot71a	8/26/98	128	N 19:19.01	W 156:06.67	8	Norris
44pilot75a	8/26/98	128	N 19:19.01	W 156:06.67	8	Norris
56pilot92a	11/7/98	442	S 11:04.60	W 099:29.27	10	Norris
56pilot94a	11/7/98	442	S 11:04.60	W 099:29.27	10	Norris
56pilot95a	11/7/98	442	S 11:04.60	W 099:29.27	10	Norris
Pseudorca crassidens						
pc8	9/3/98	130	N 13:23.17	W 153:33.95	8	ITI
pc28	9/3/98	130	N 13:23.17	W 153:33.95	8	ITI
pc40	9/3/98	130	N 13:23.17	W 153:33.95	8	ITI
pc21	9/3/98	130	N 13:23.17	W 153:33.95	8	ITI
pc15	9/3/98	130	N 13:23.17	W 153:33.95	8	ITI
pc26	9/3/98	130	N 13:23.17	W 153:33.95	8	ITI

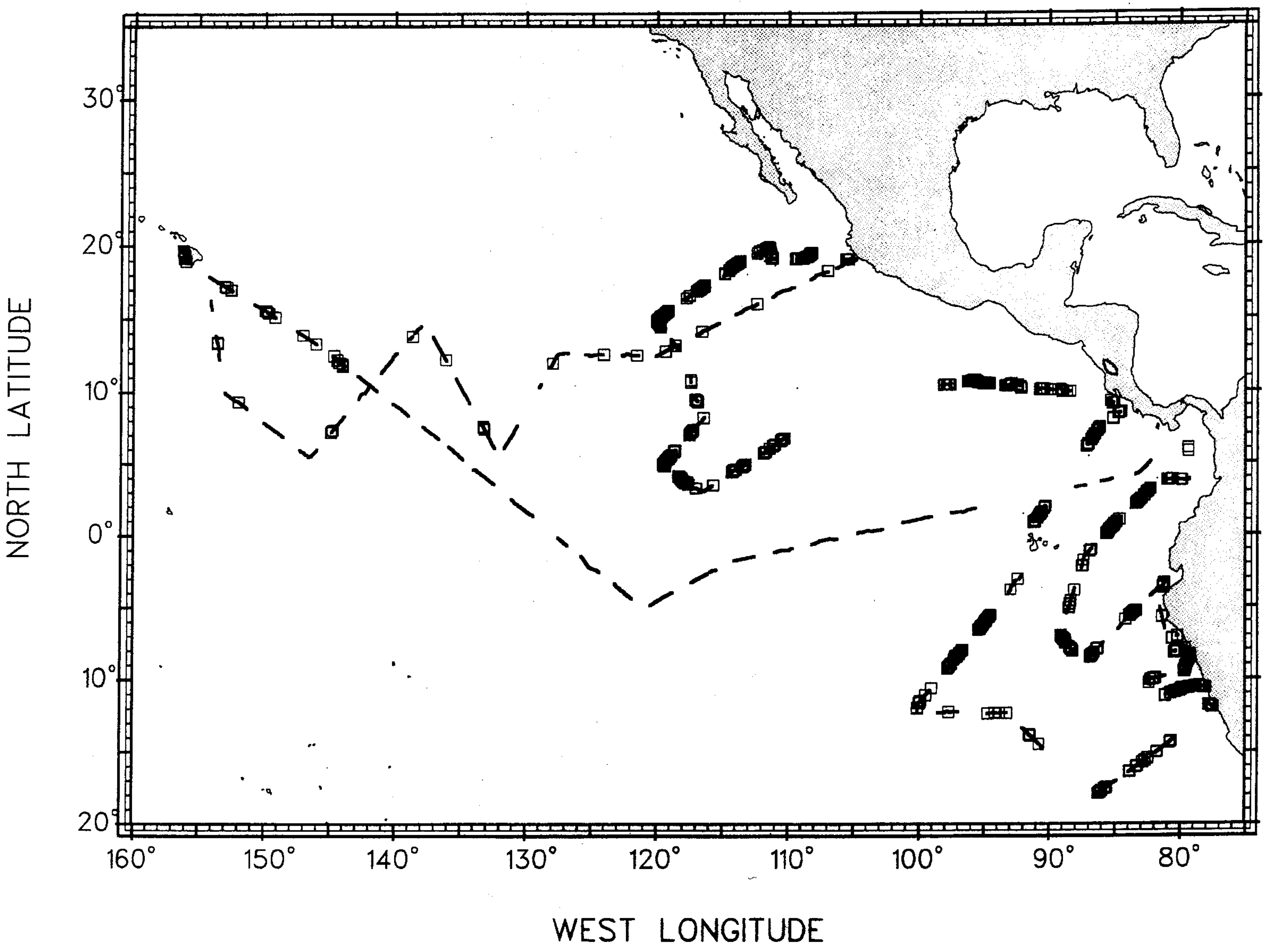


Figure 1. SPAM 1998 acoustic trackline. Dashed line indicates the track of the towed array. Boxes indicate acoustic detections of clear delphinid whistles. Acoustic detections were made on the trackline between Panama and Hawaii, however they were not systematically documented until the end of that leg.

(a)
(b)
(c)

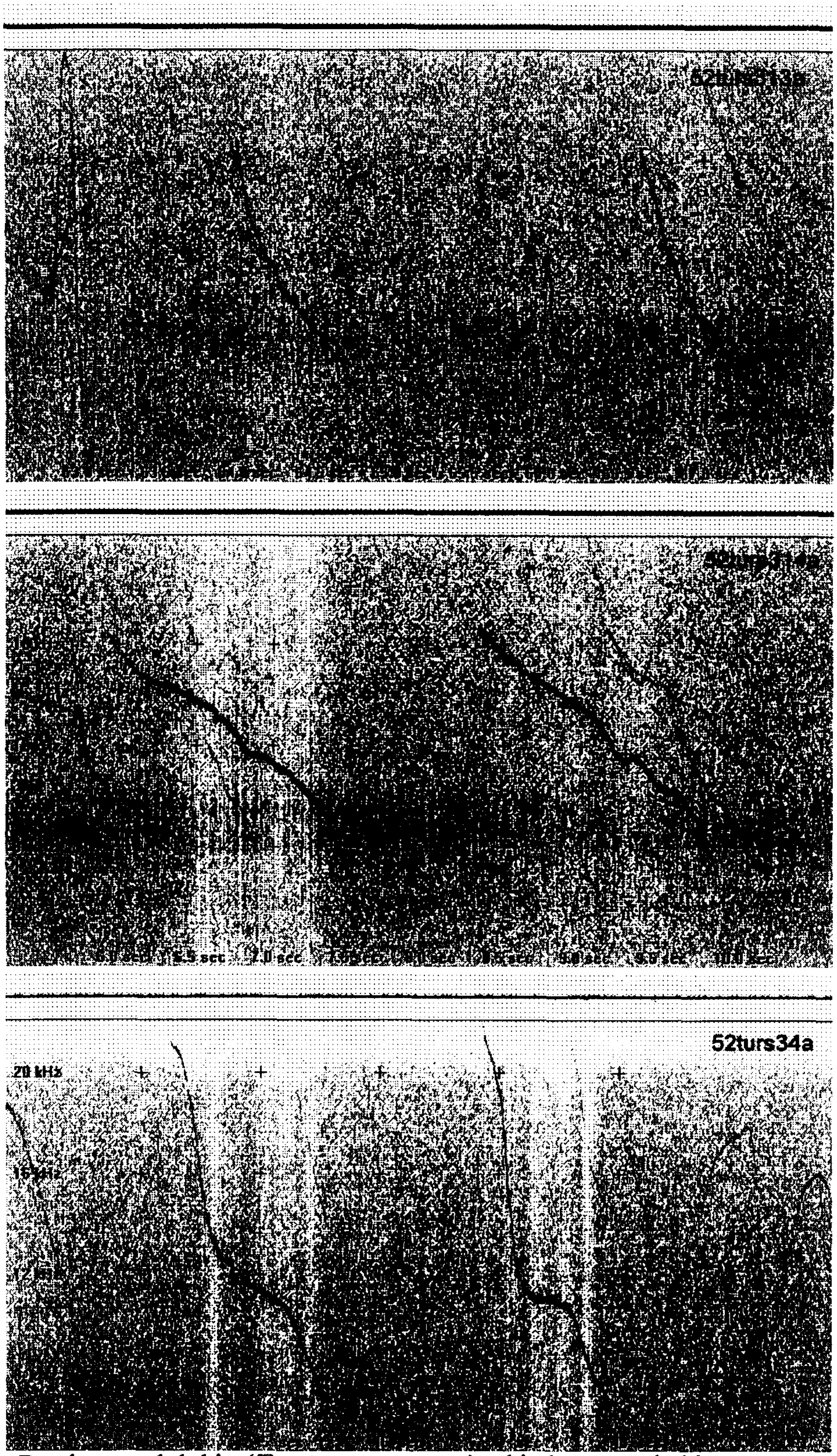


Figure 2 (a)-(c). Bottlenose dolphin (*Tursiops truncatus*) whistles recorded in the Eastern Tropical Pacific ocean. Sighting number, date, location, group size estimates, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

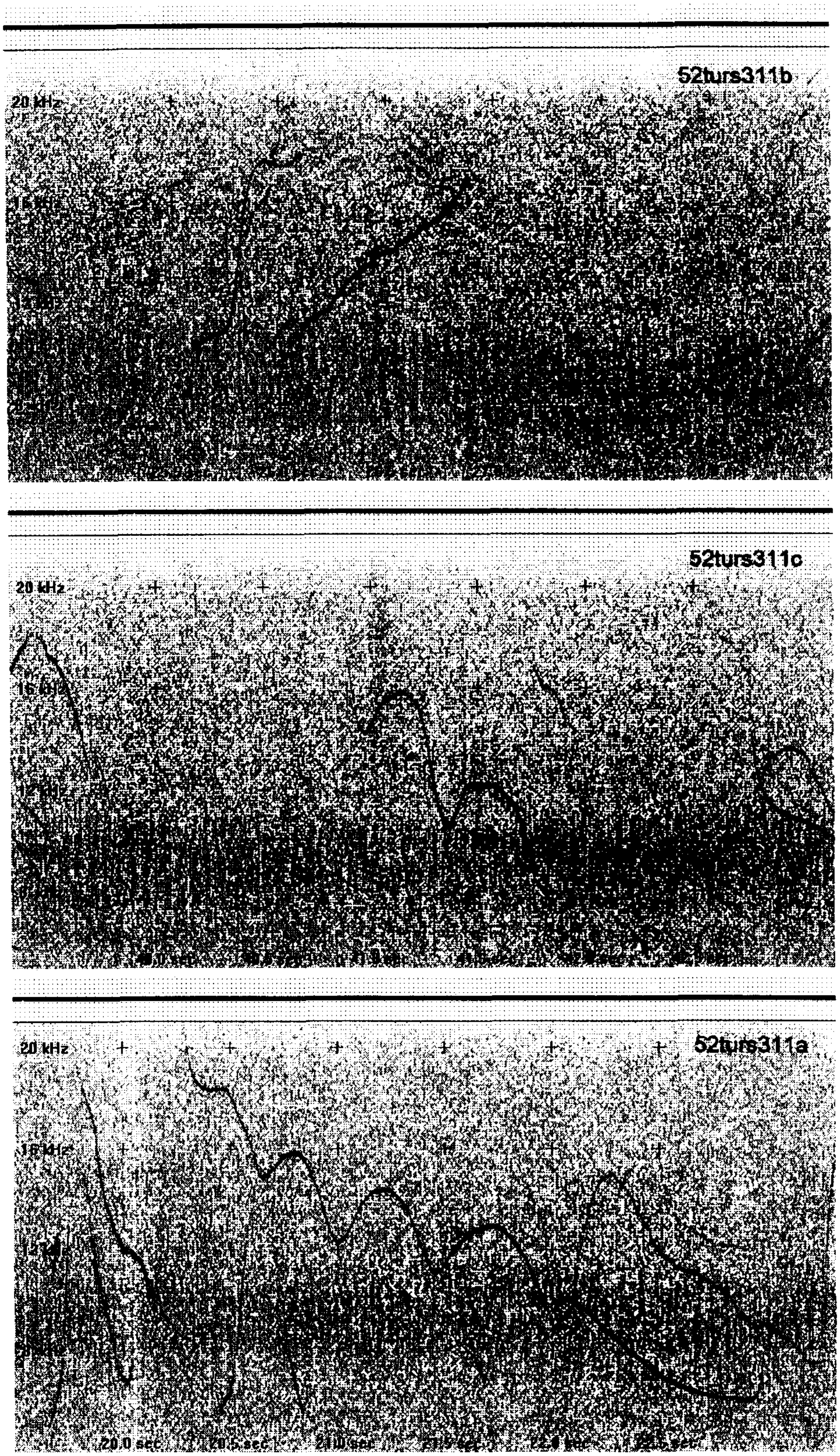


Figure 3 (a)-(c). Bottlenose dolphin (*Tursiops truncatus*) whistles recorded in the Eastern Tropical Pacific ocean. Sighting number, date, location, group size estimates, and hydrophones used are given for each spectrogram in Table 1.

(a)
(b)
(c)

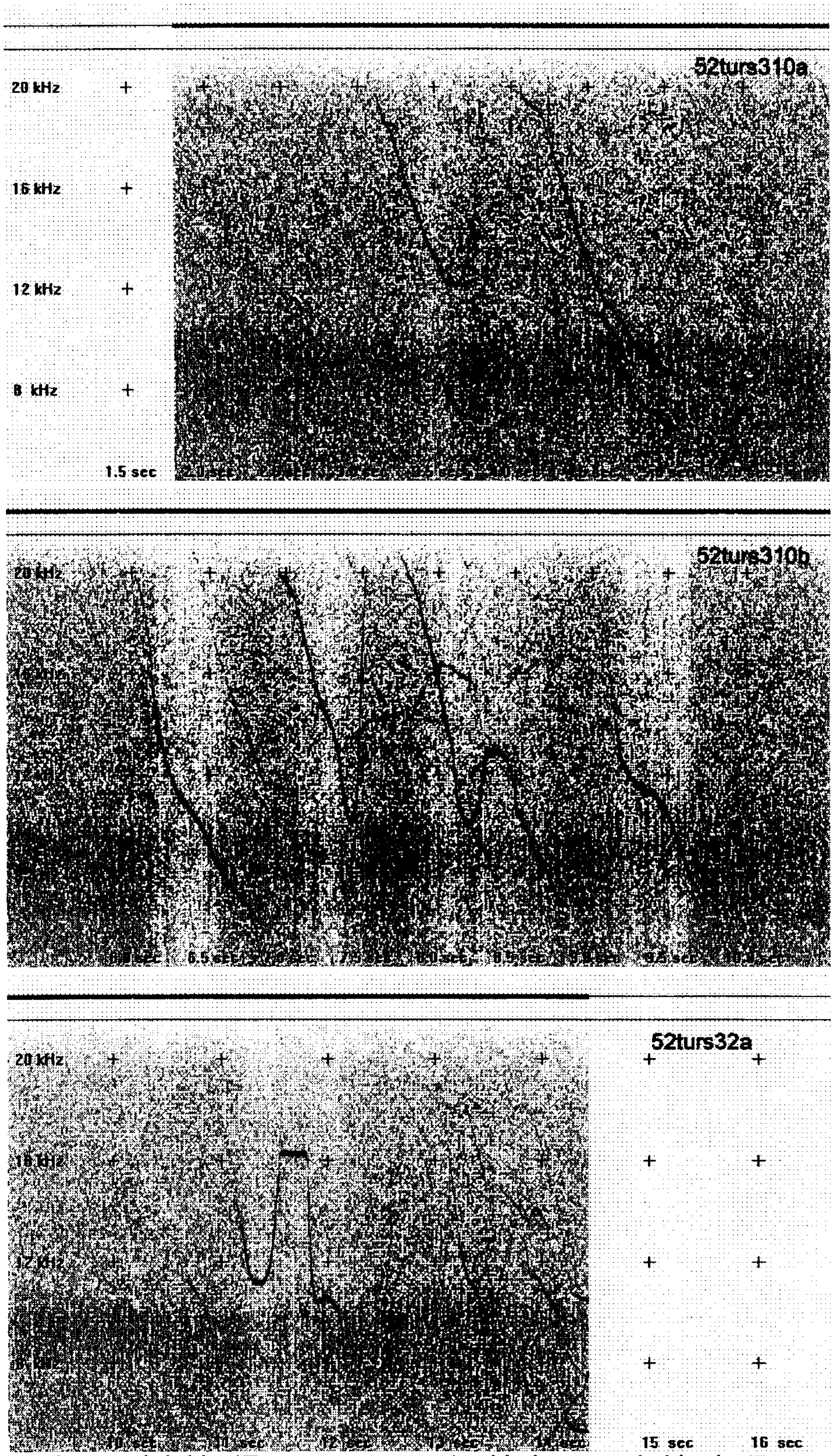


Figure 4 (a)-(c). Bottlenose dolphin (*Tursiops truncatus*) whistles recorded in the Eastern Tropical Pacific ocean. Sighting number, date, location, group size estimates, and hydrophones used are given for each spectrogram in Table 1.

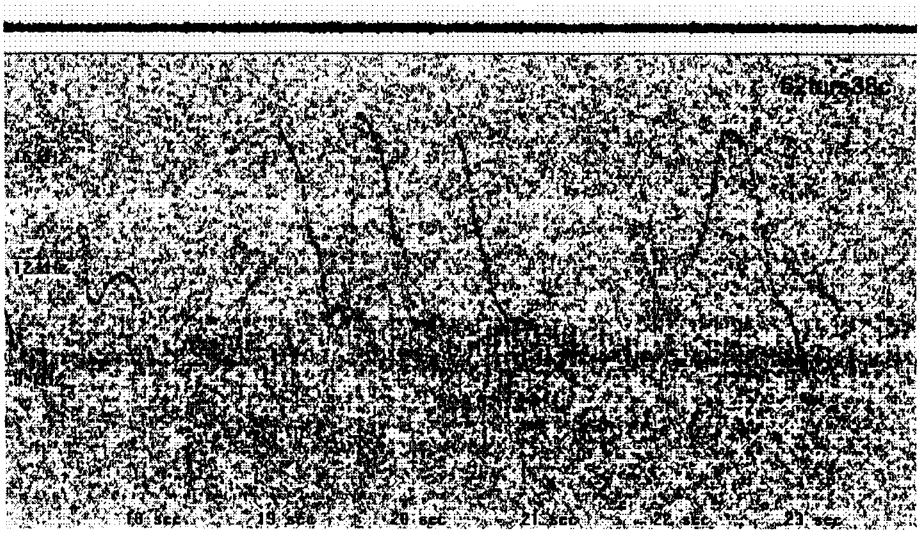


Figure 5. Bottlenose dolphin (*Tursiops truncatus*) whistles recorded in the Eastern Tropical Pacific ocean. Sighting number, date, location, group size estimate, and hydrophones used are given in Table 1.

(a)

(b)

(c)

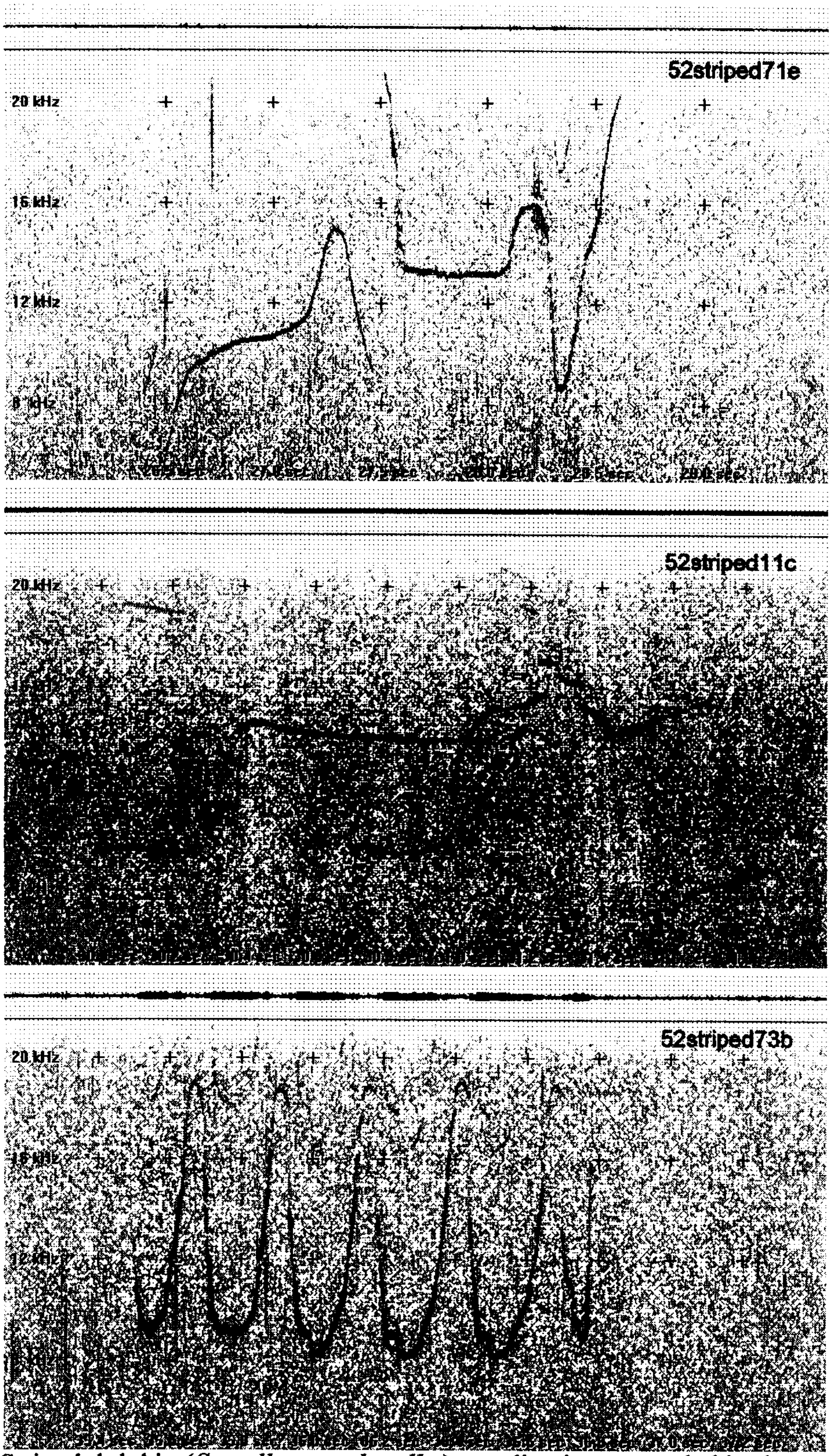


Figure 6 (a)-(c). Striped dolphin (*Stenella coeruleoalba*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

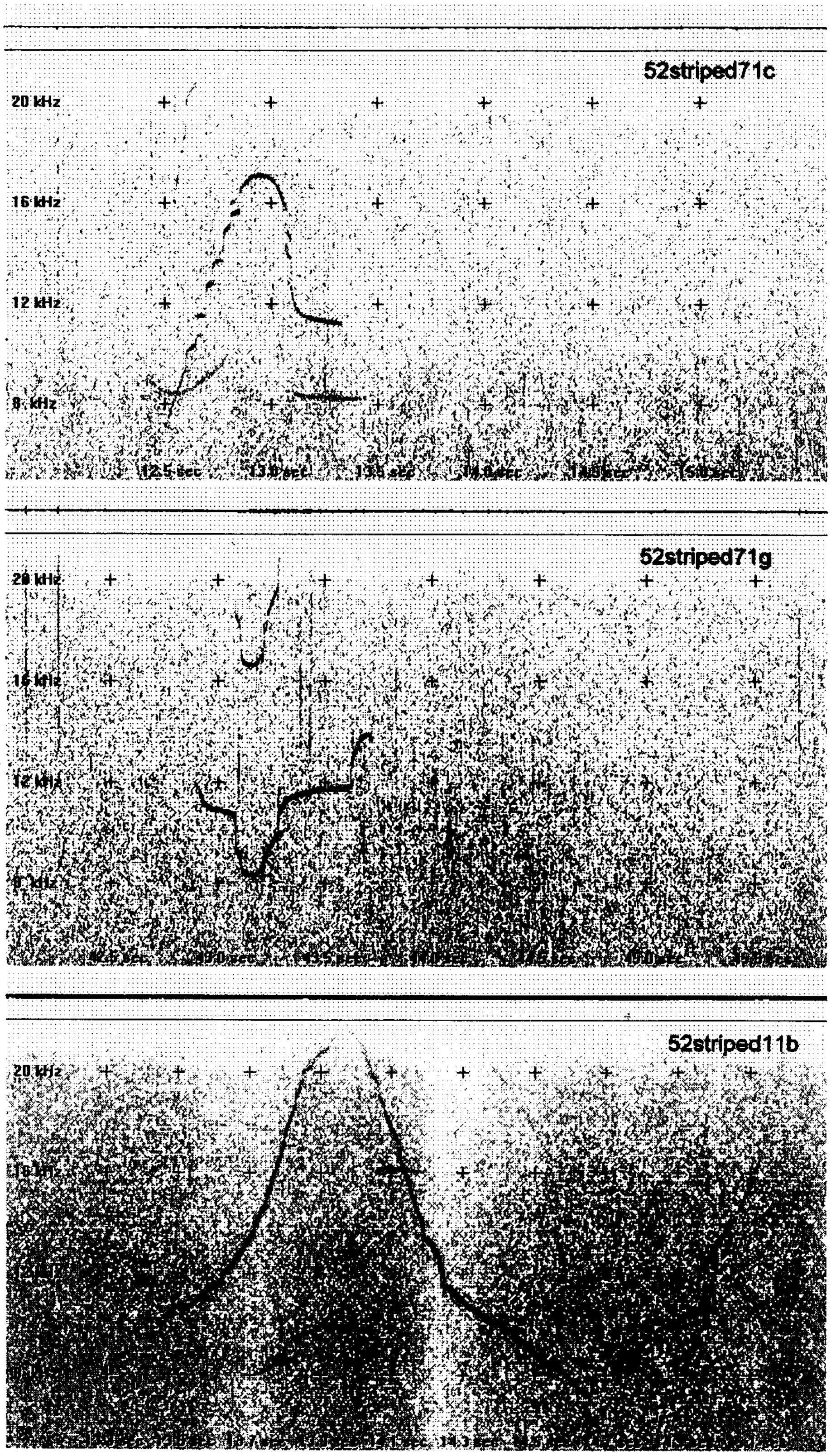


Figure 7 (a)-(c): Striped dolphin (*Stenella coeruleoalba*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

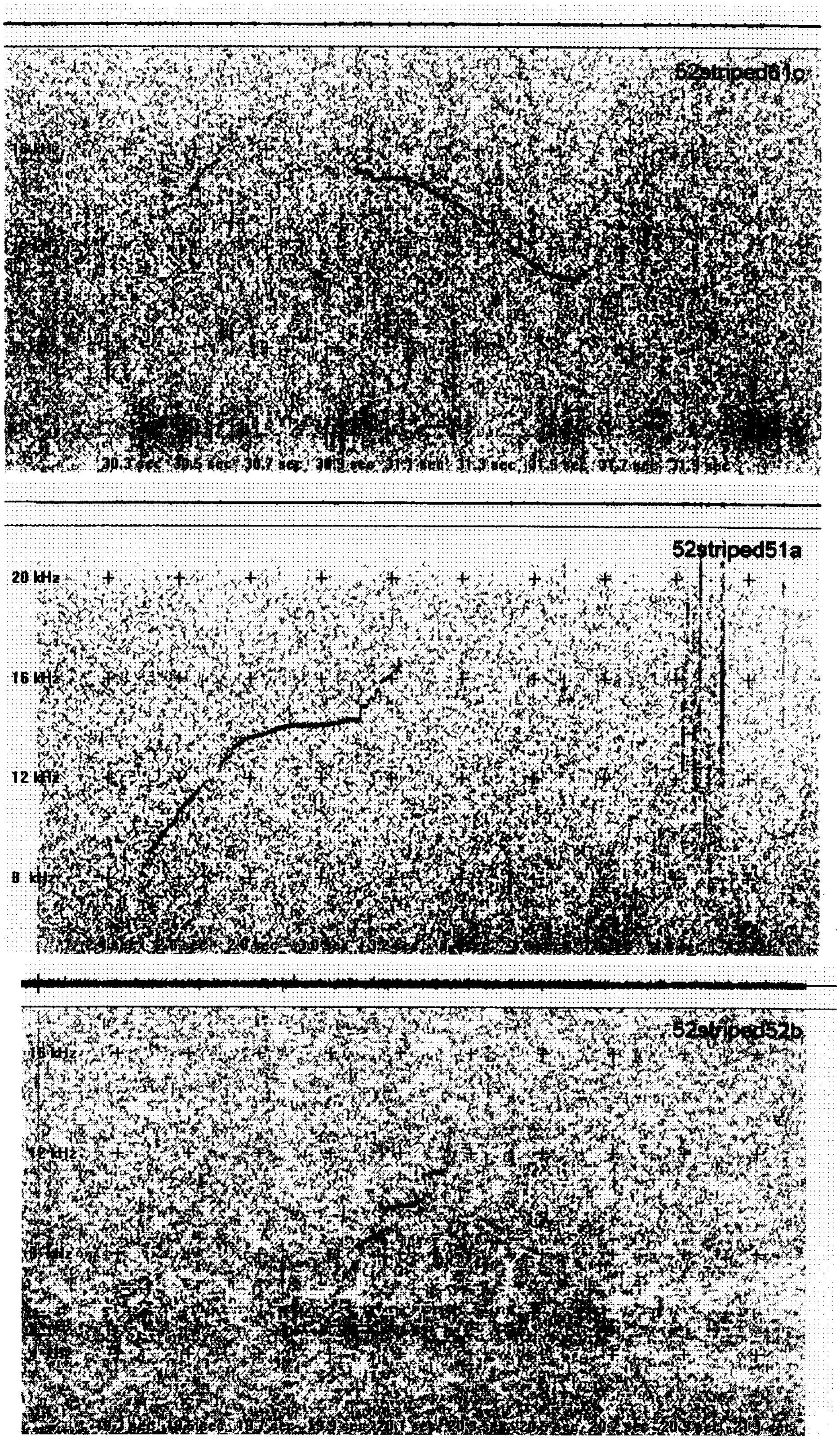


Figure 8 (a)-(c). Striped dolphin (*Stenella coeruleoalba*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

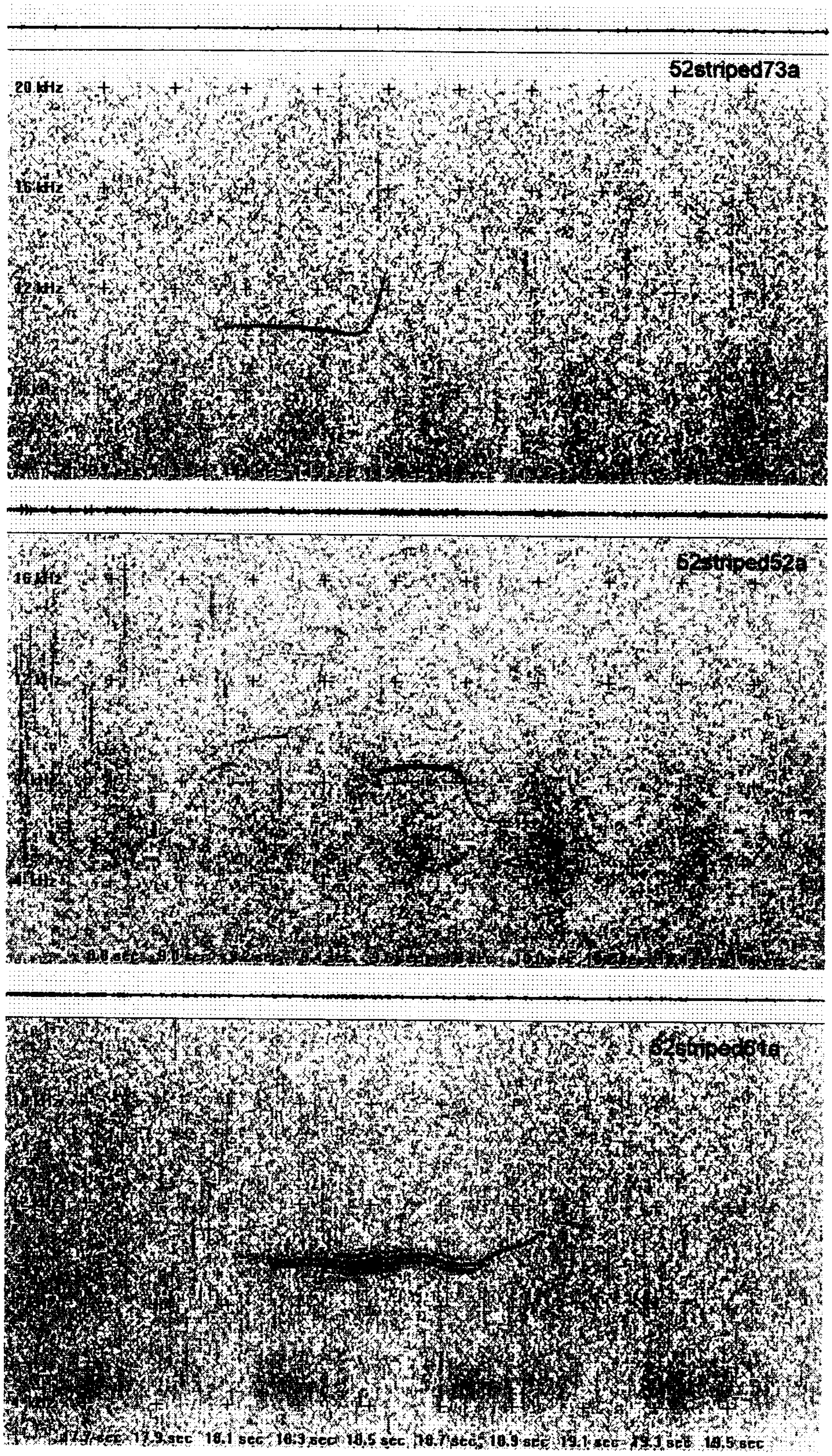


Figure 9 (a)-(c). Striped dolphin (*Stenella coeruleoalba*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

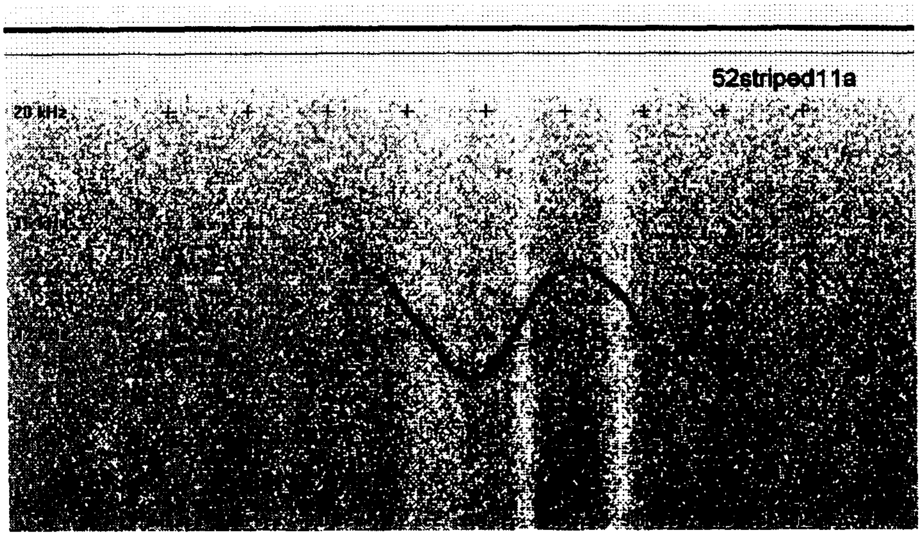


Figure 10. Striped dolphin (*Stenella coeruleoalba*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given in Table 1.

(a)

(b)

(c)

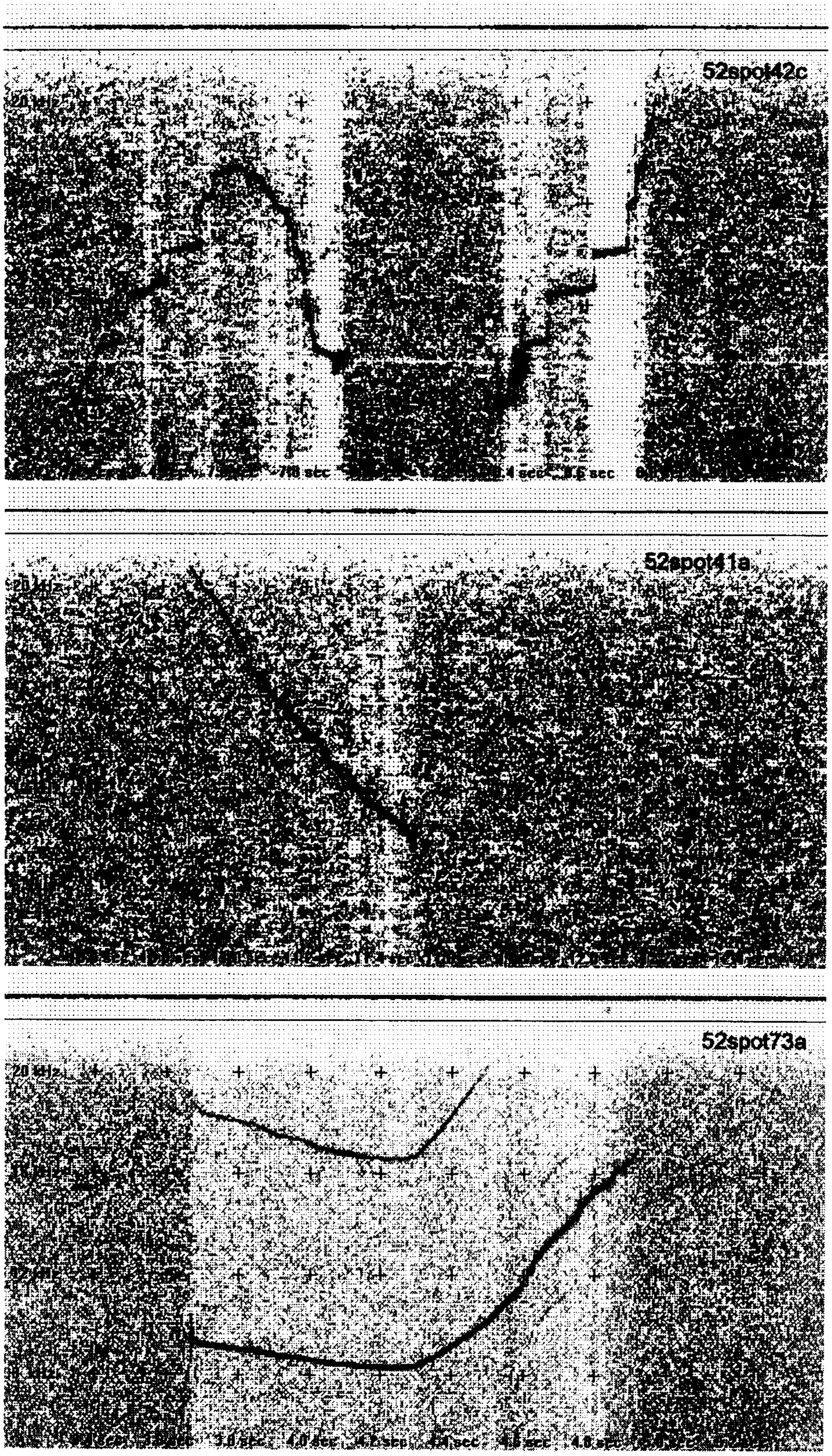


Figure 11 (a)-(c). Offshore pantropical spotted dolphin (*Stenella attenuata*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

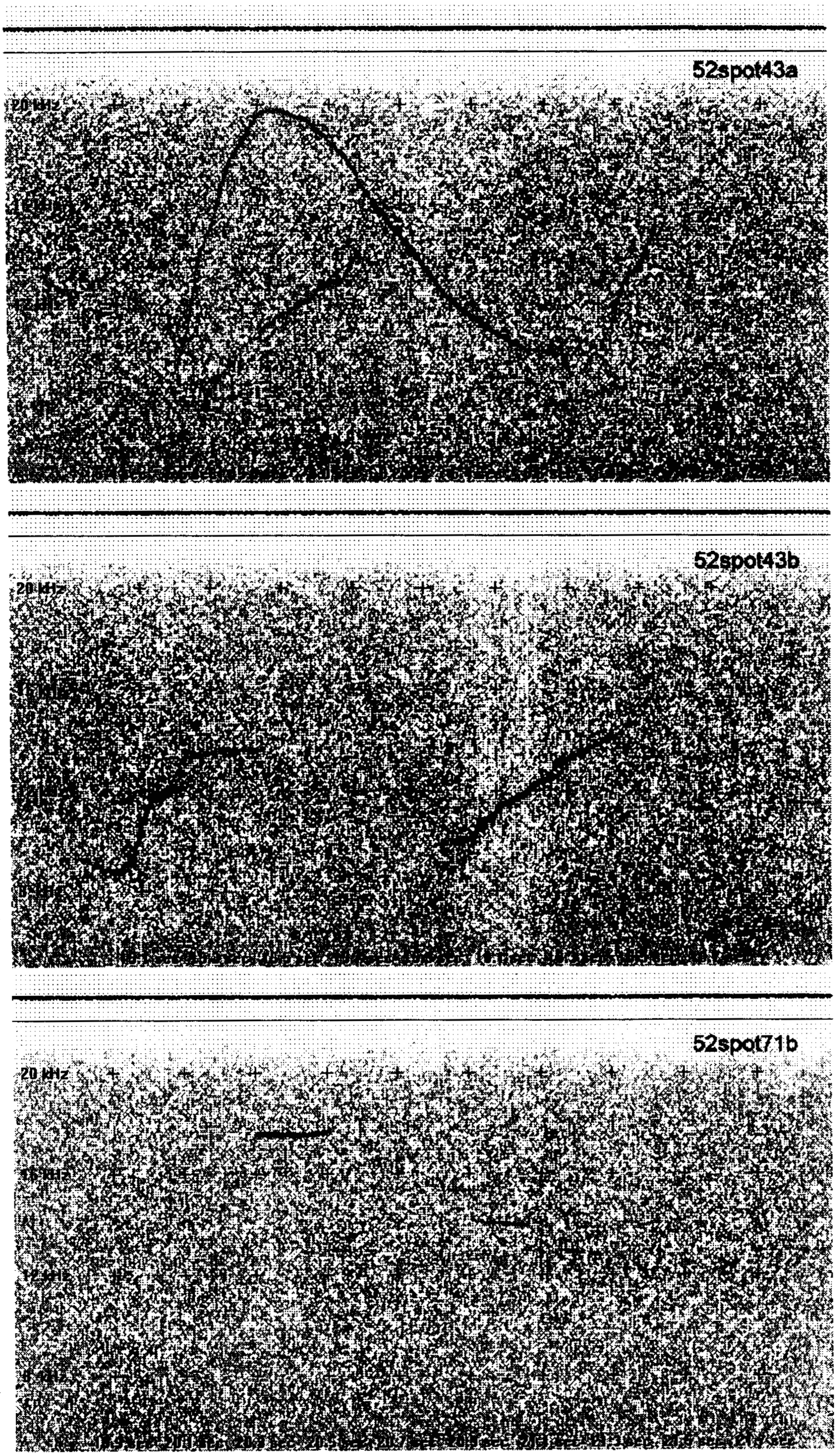


Figure 12 (a)-(c). Offshore pantropical spotted dolphin (*Stenella attenuata*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1

(a)

(b)

(c)

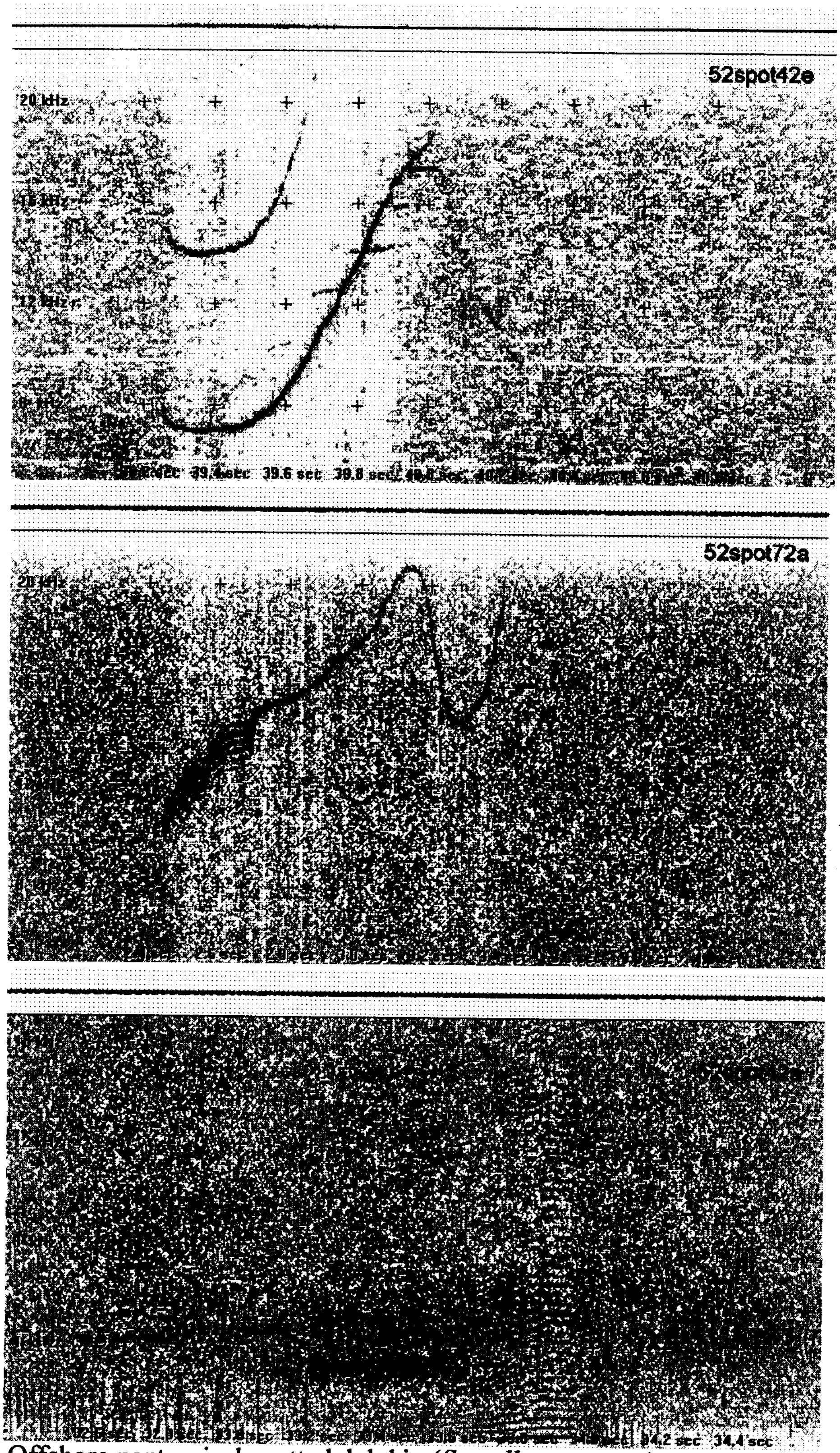


Figure 13 (a)-(c). Offshore pantropical spotted dolphin (*Stenella attenuata*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

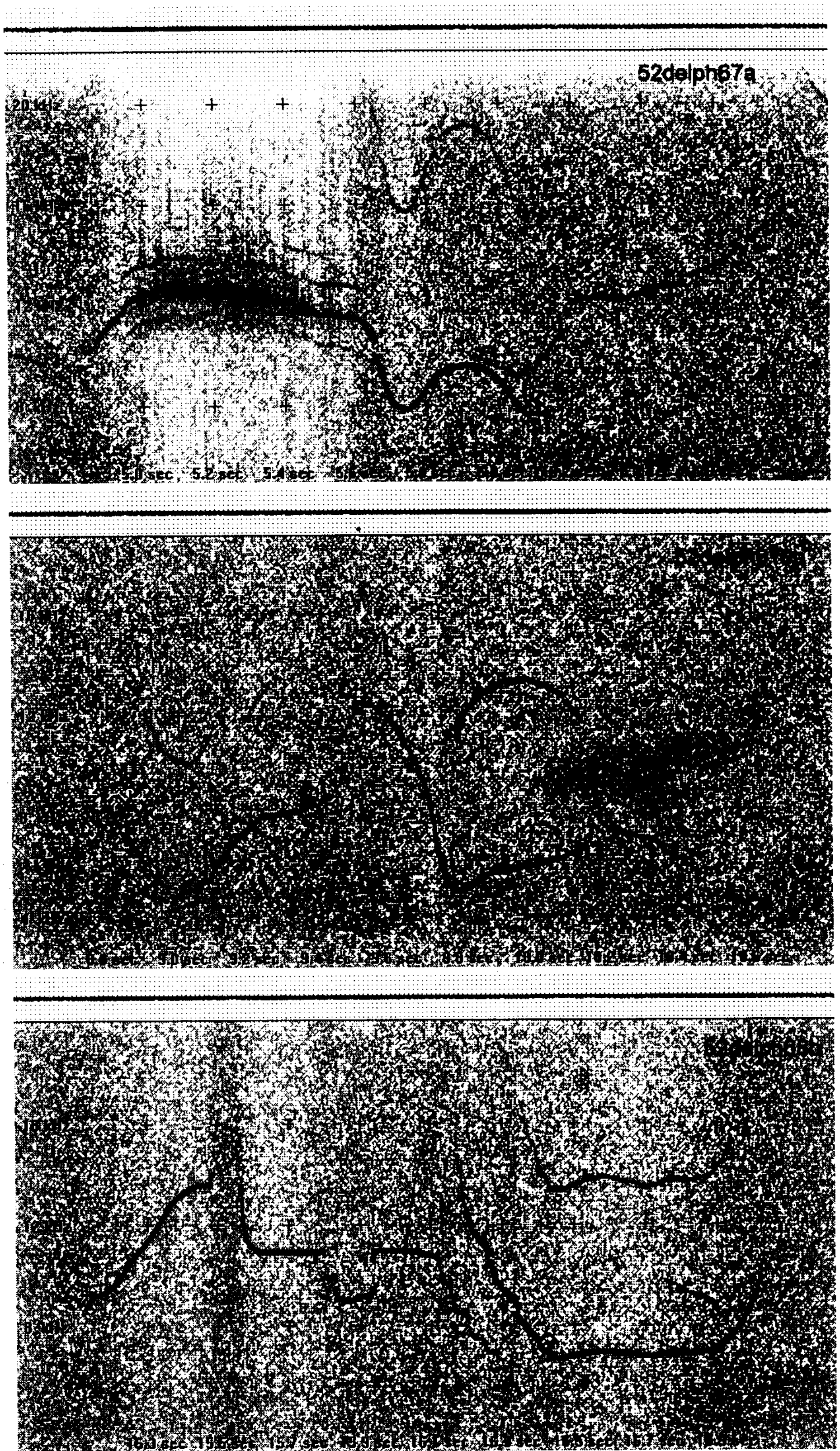
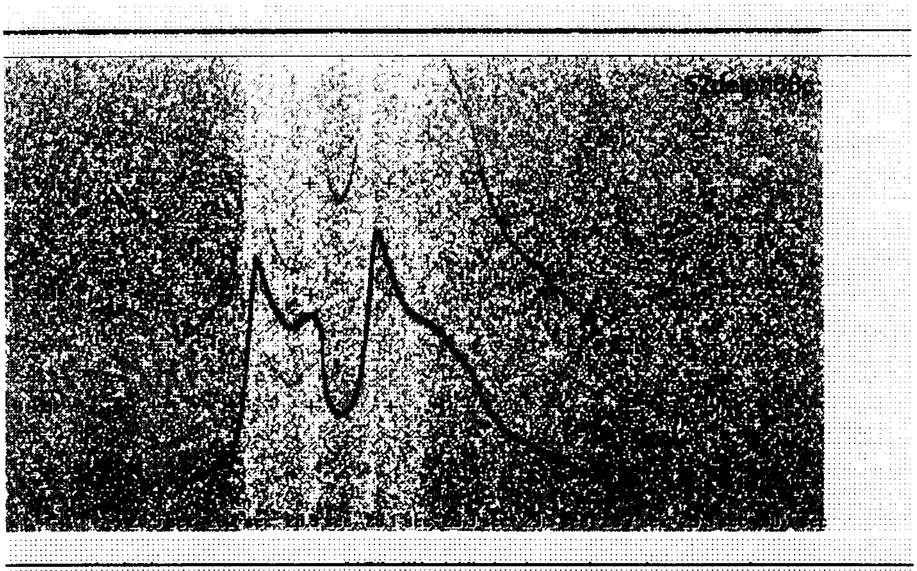
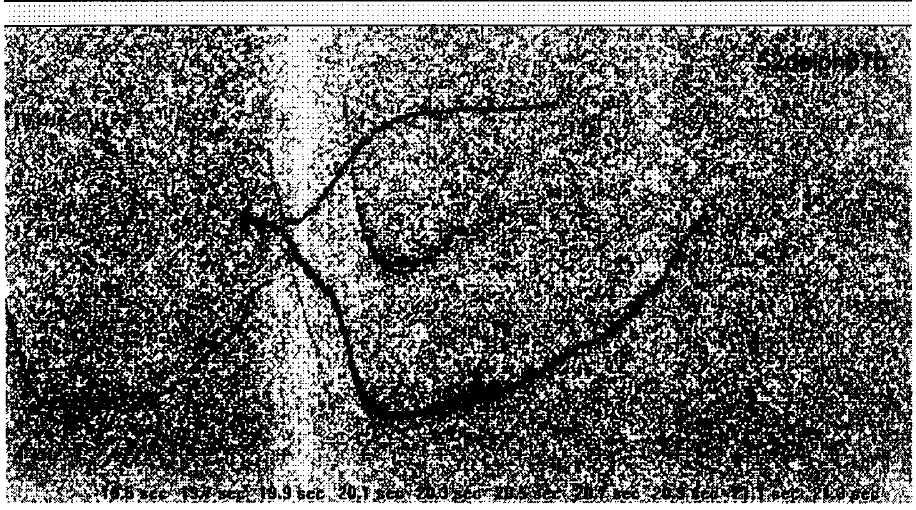


Figure 14 (a)-(c). Short-beaked common dolphin (*Delphinus delphis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)



(b)



(c)

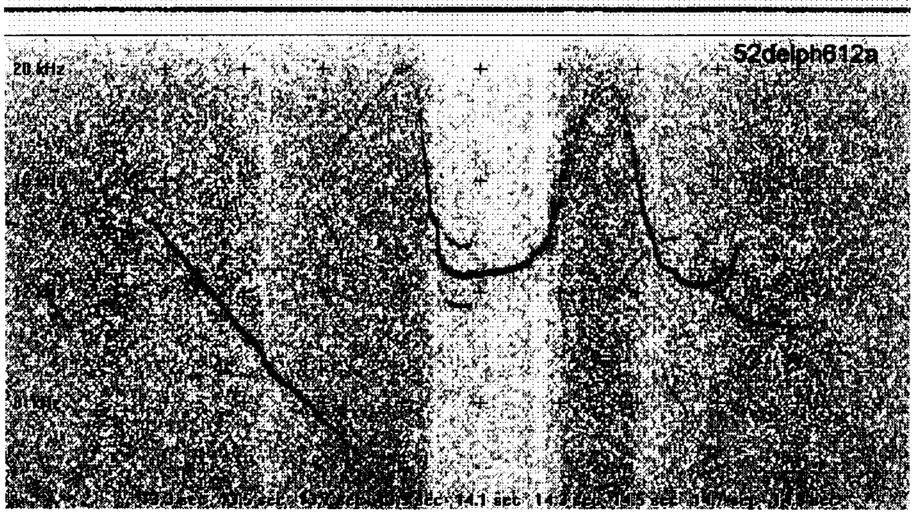


Figure 15 (a)-(c). Short-beaked common dolphin (*Delphinus delphis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

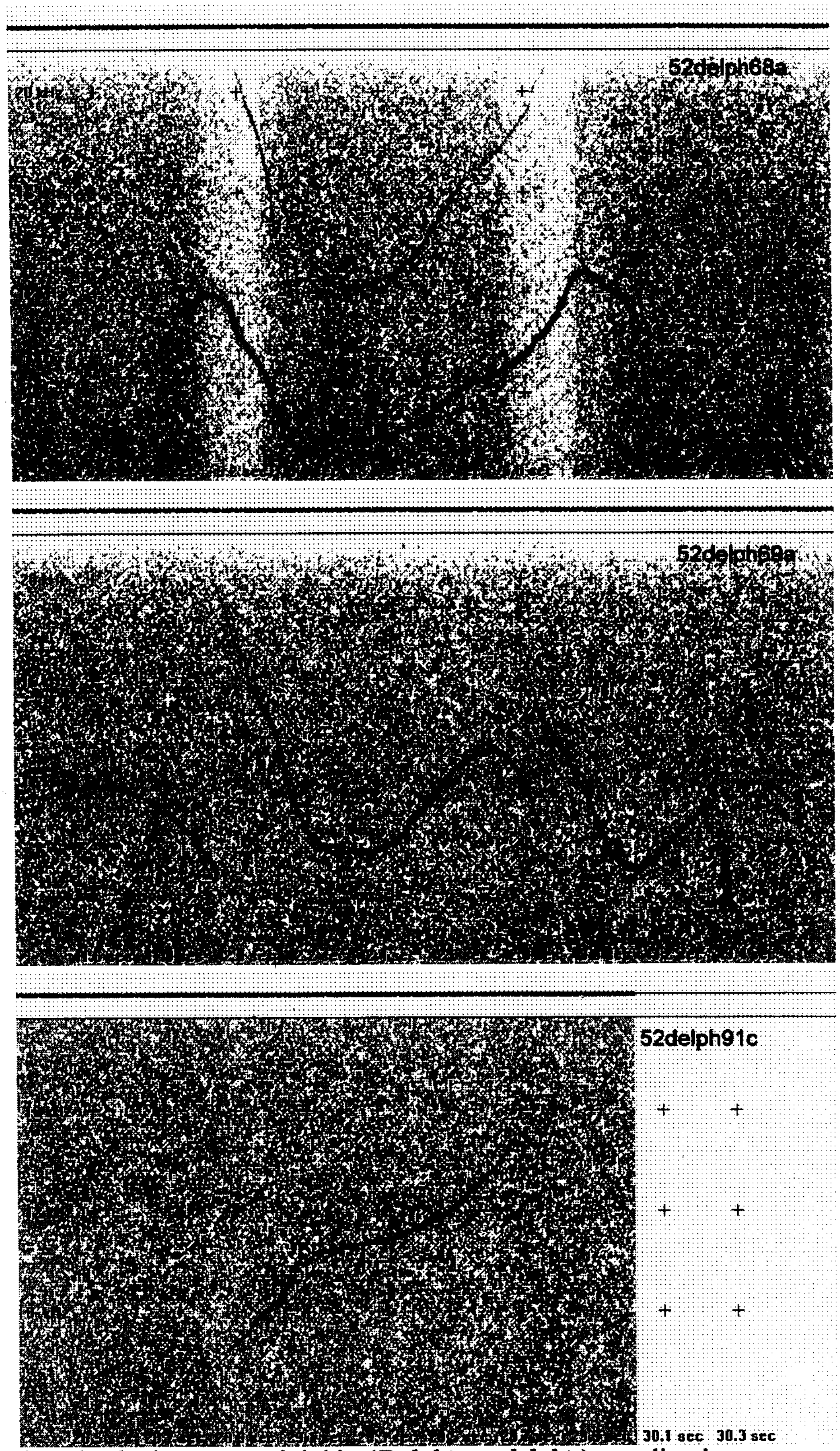
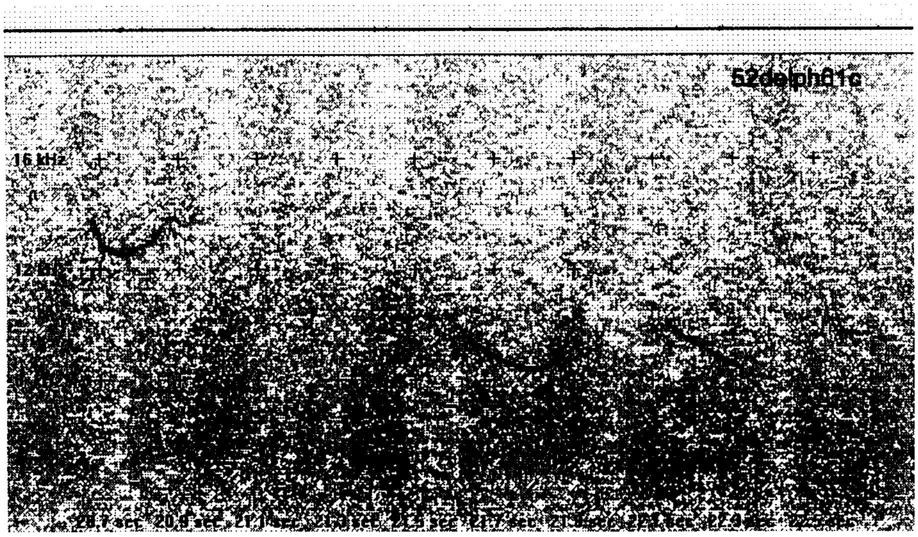
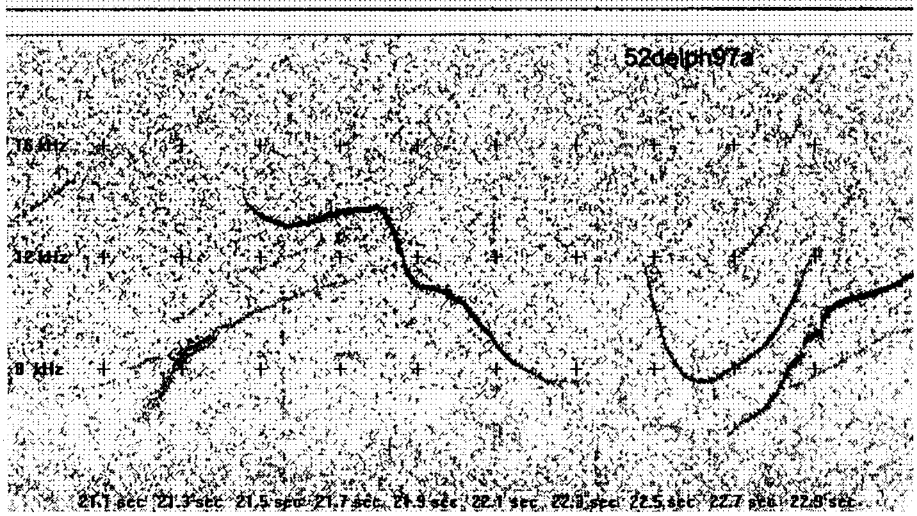


Figure 16 (a)-(c). Short-beaked common dolphin (*Delphinus delphis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)



(b)



(c)

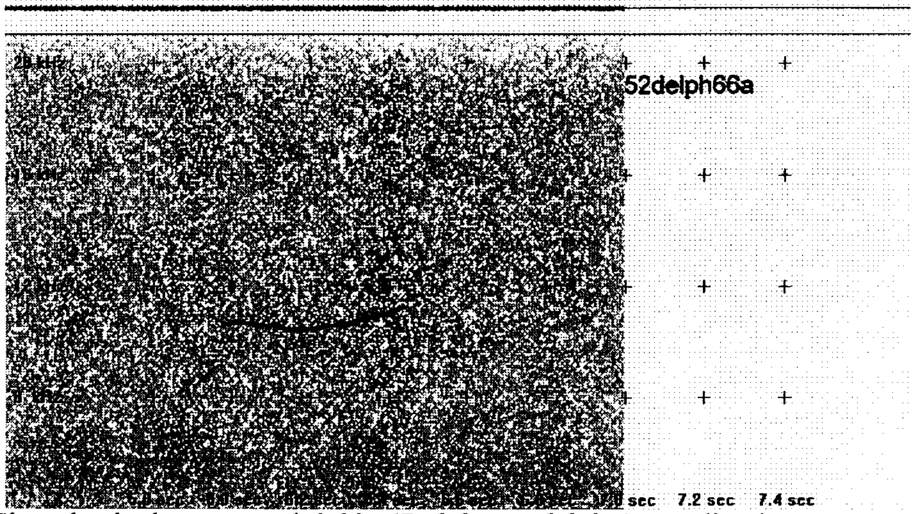


Figure 17 (a)-(c). Short-beaked common dolphin (*Delphinus delphis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

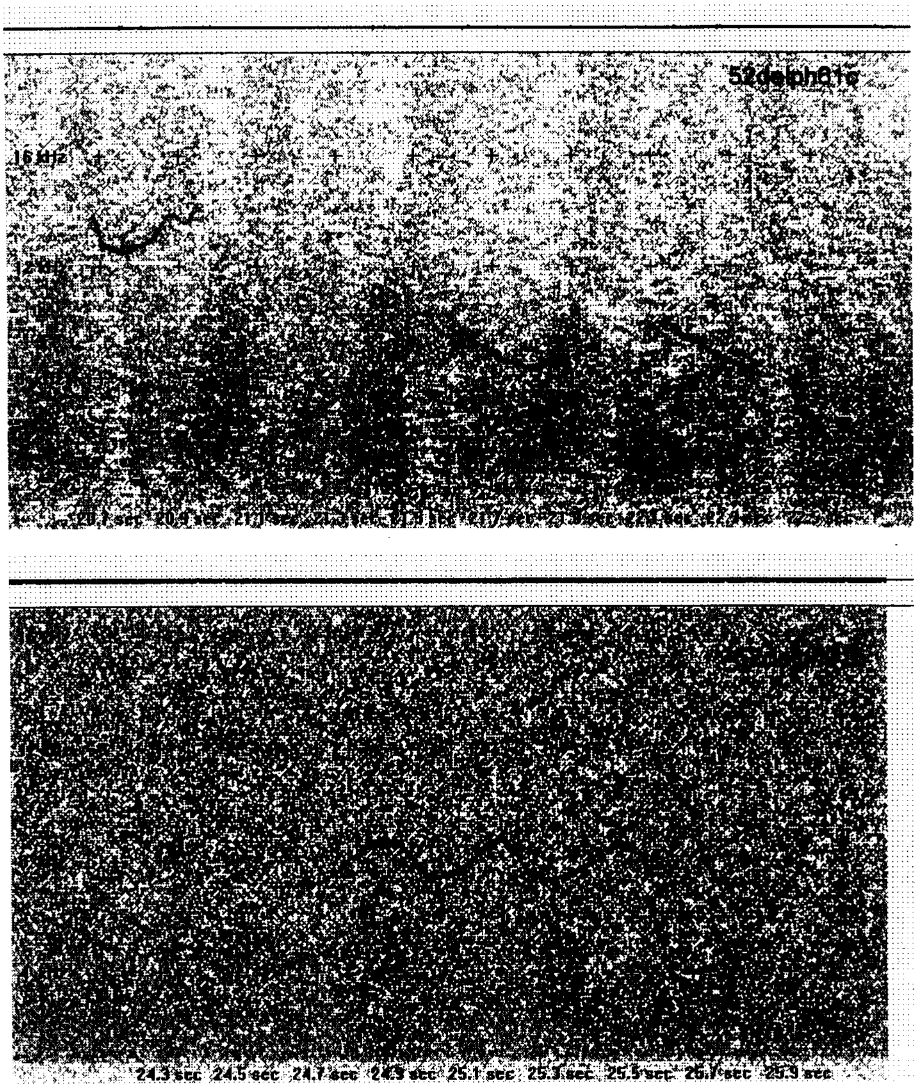


Figure 18 (a)-(b). Short-beaked common dolphin (*Delphinus delphis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

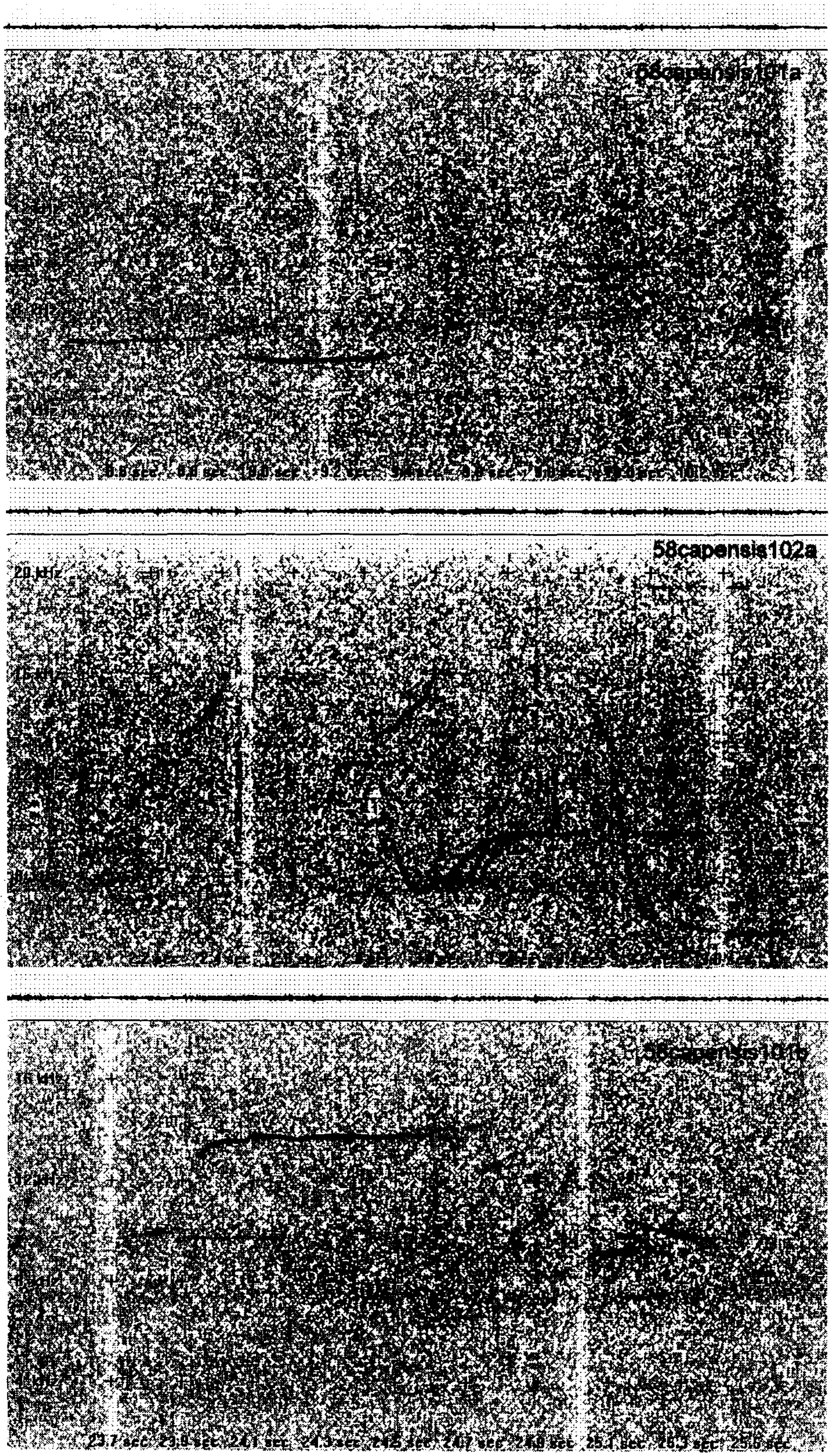


Figure 19 (a)-(c). Long-beaked common dolphin (*Delphinus capensis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

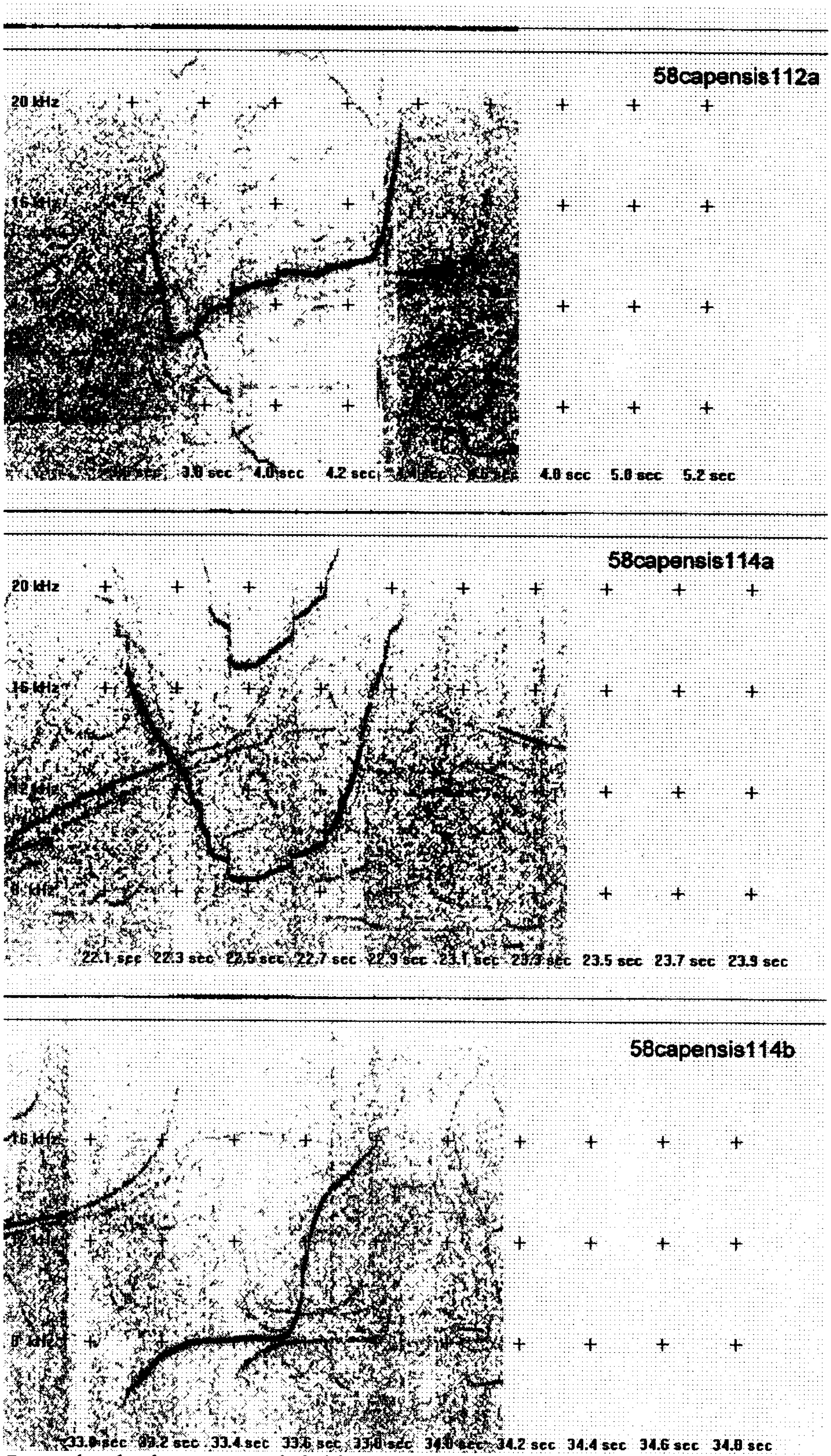
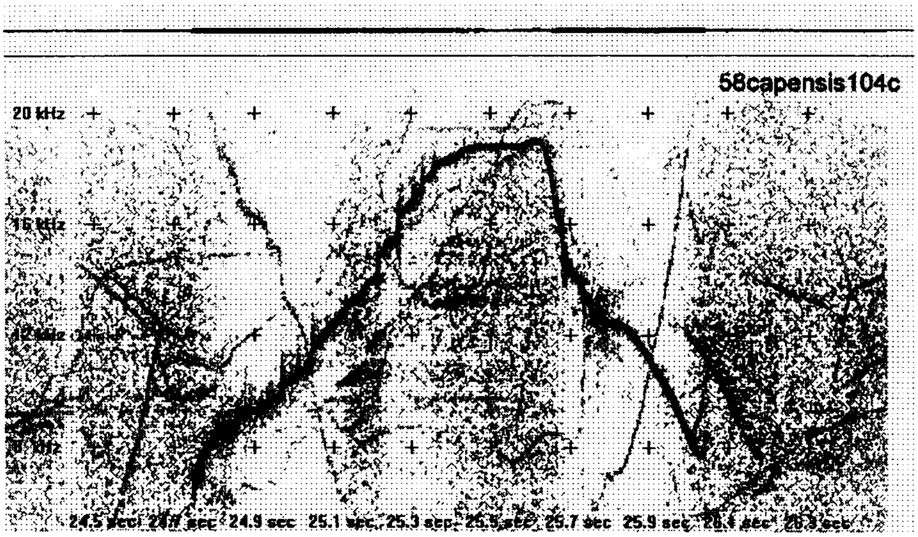
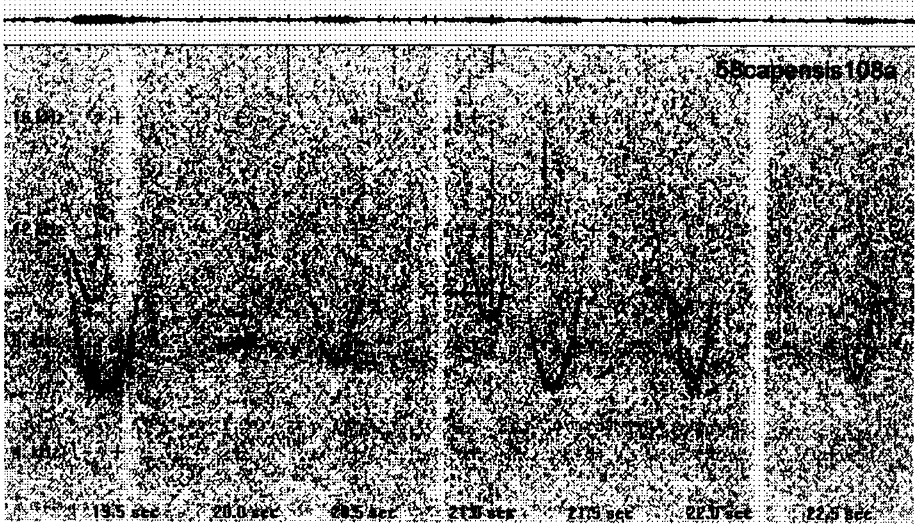


Figure 20 (a)-(c). Long-beaked common dolphin (*Delphinus capensis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)



(b)



(c)

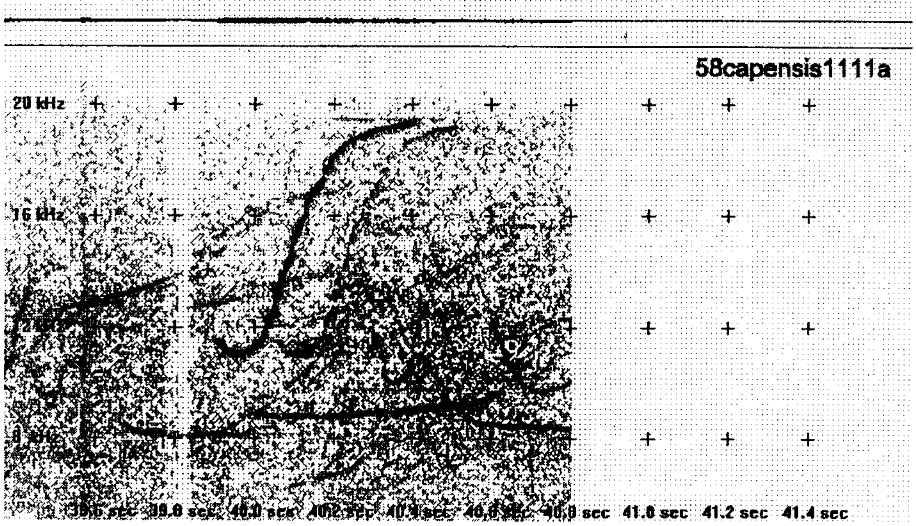


Figure 21 (a)-(c). Long-beaked common dolphin (*Delphinus capensis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

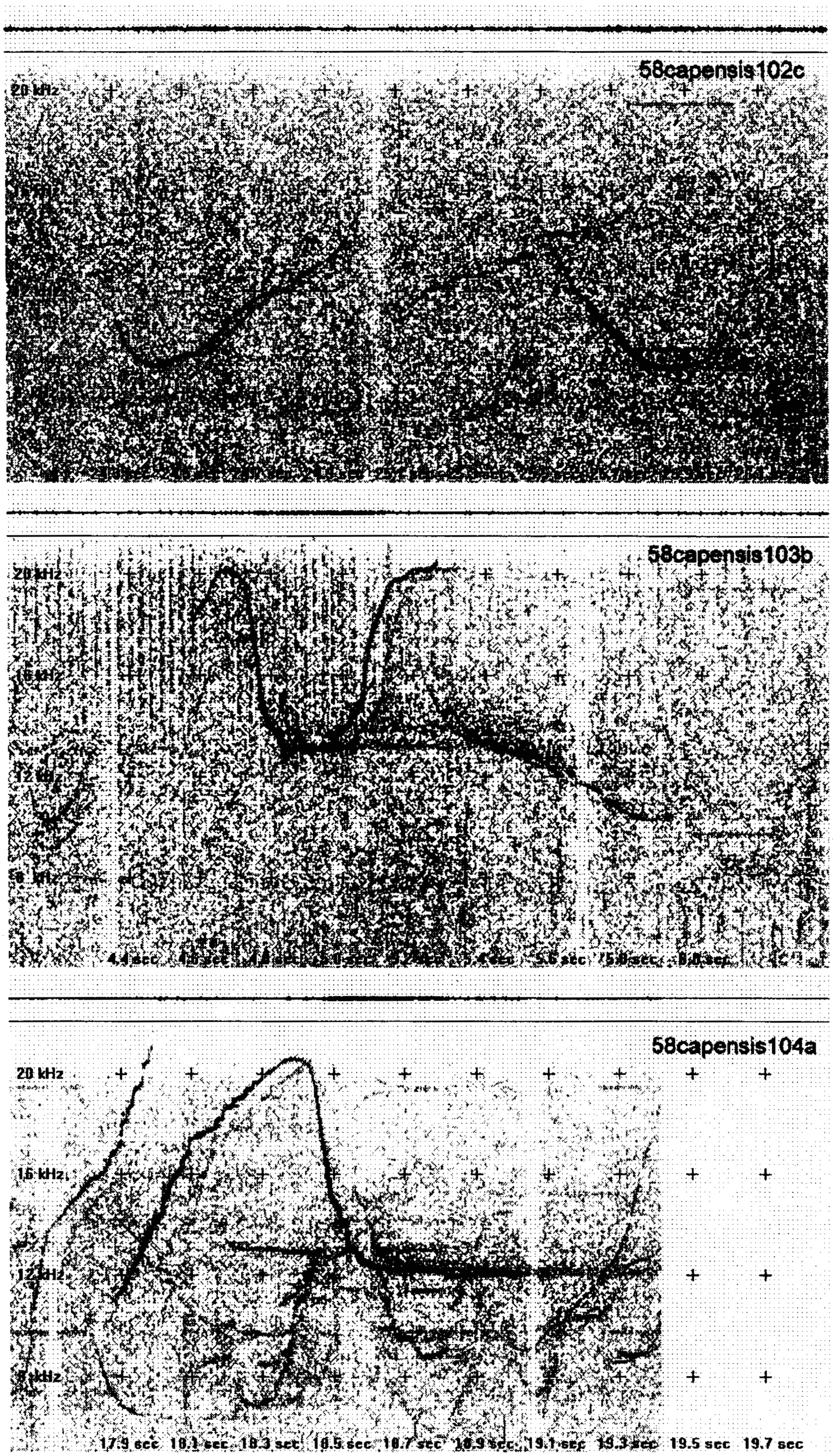


Figure 22 (a)-(c). Long-beaked common dolphin (*Delphinus capensis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

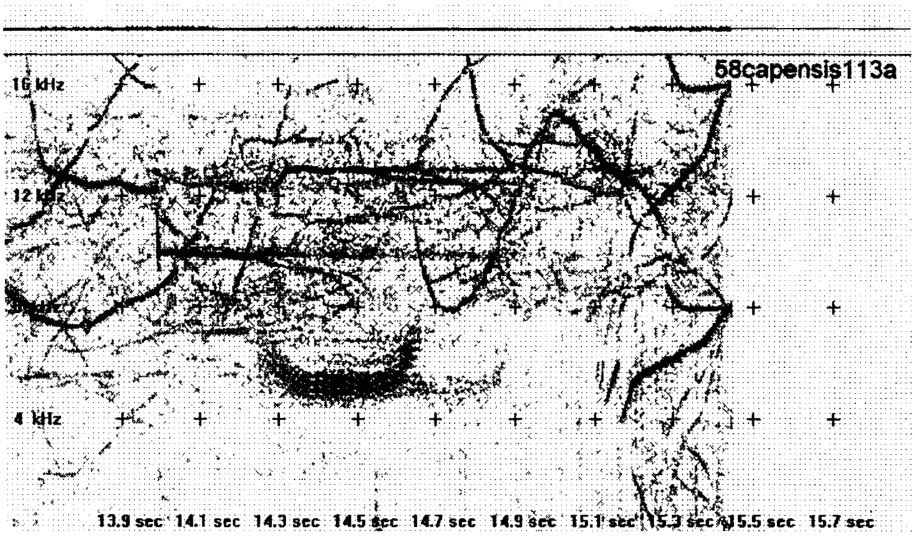


Figure 23. Long-beaked common dolphin (*Delphinus capensis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimates, and hydrophones used are given in Table 1.

(a)

(b)

(c)

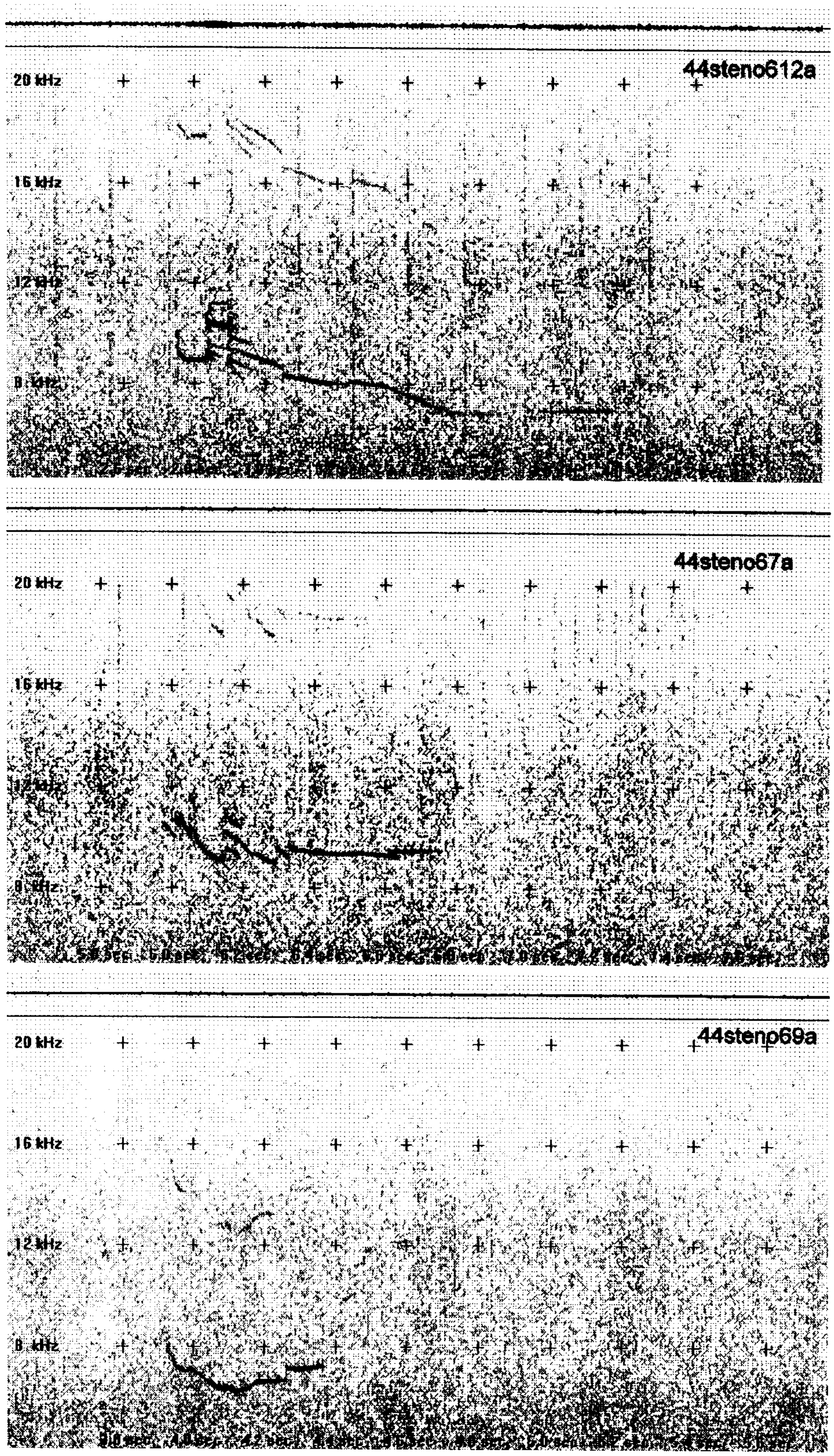


Figure 24 (a)-(c). Rough-toothed dolphin (*Steno bredanensis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

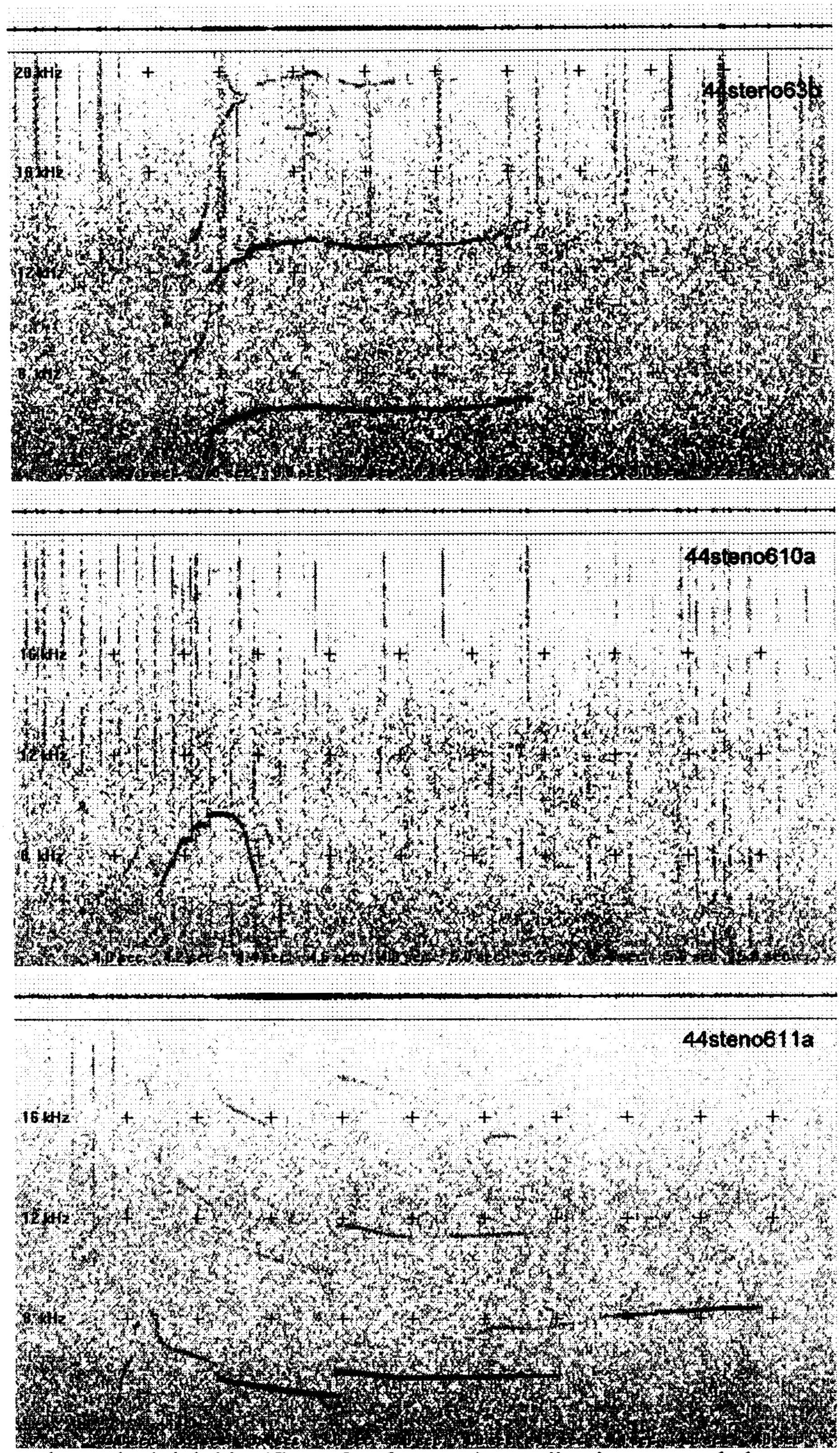
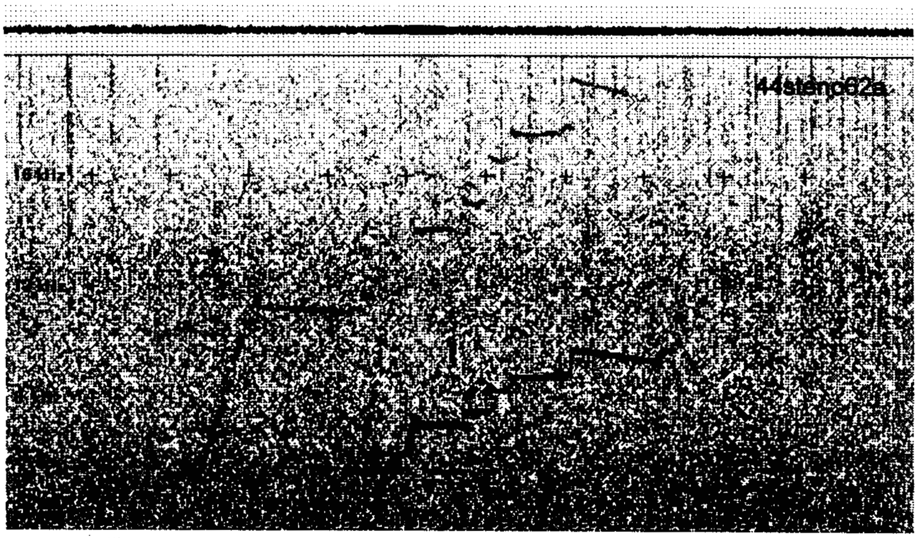
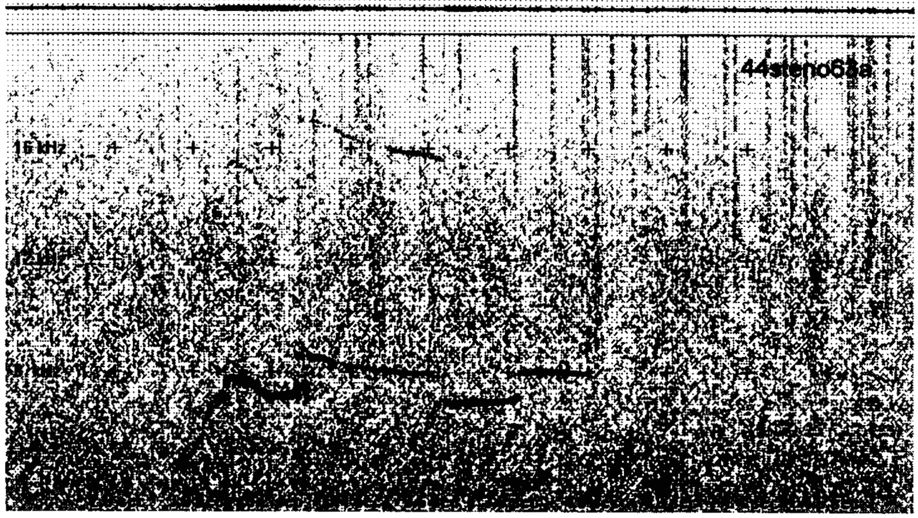


Figure 25 (a)-(c). Rough-toothed dolphin (*Steno bredanensis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)



(b)



(c)

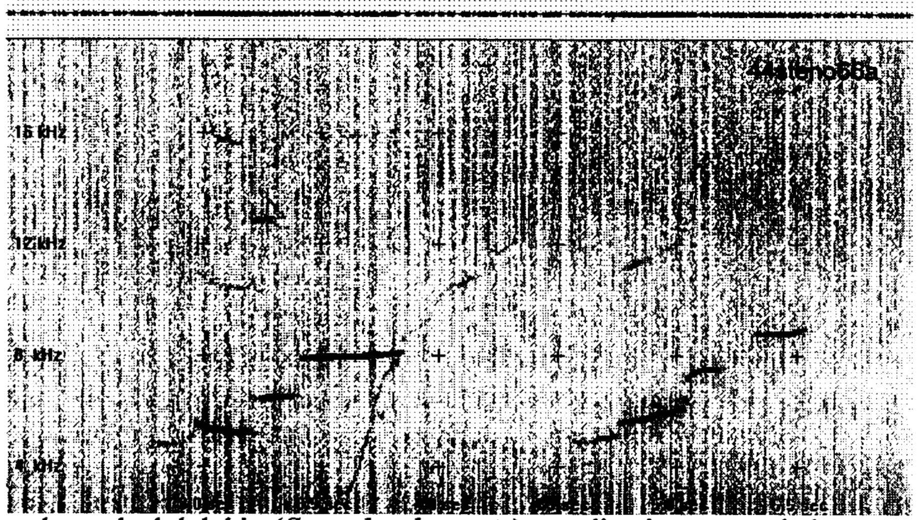
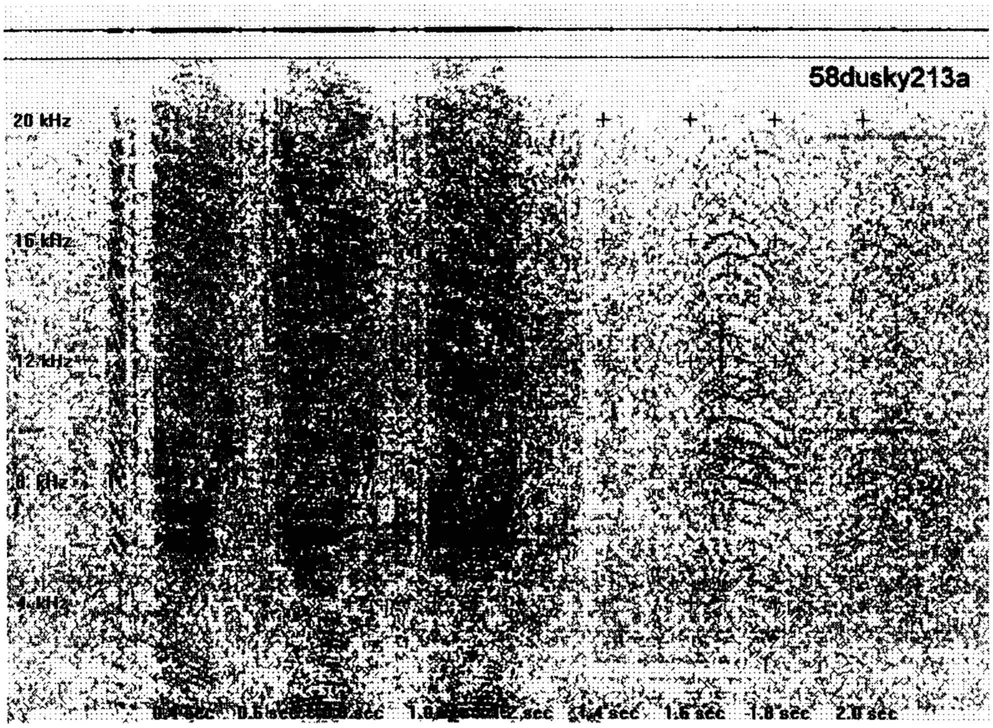


Figure 26 (a)-(c). Rough-toothed dolphin (*Steno bredanensis*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)



(b)

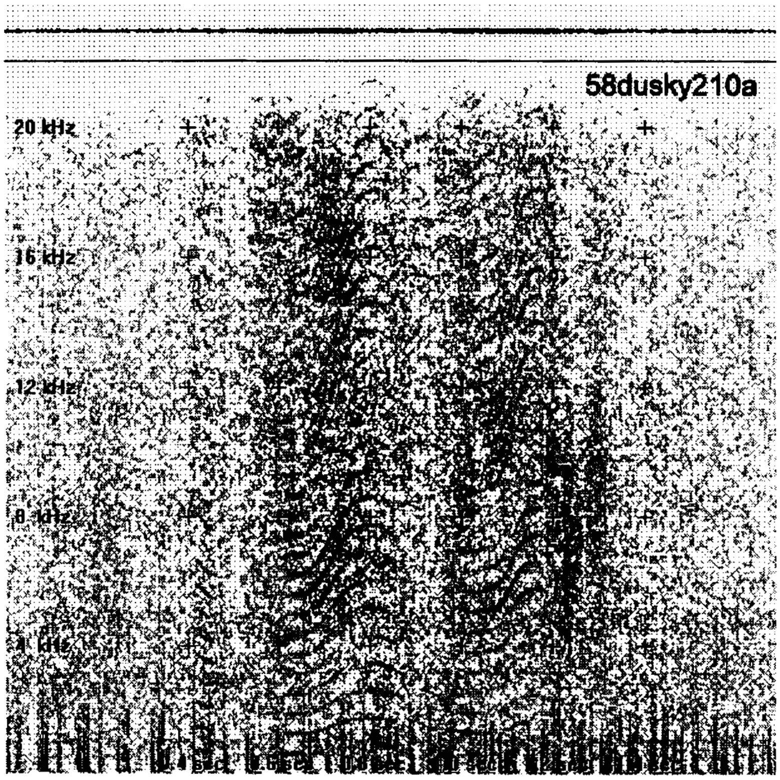
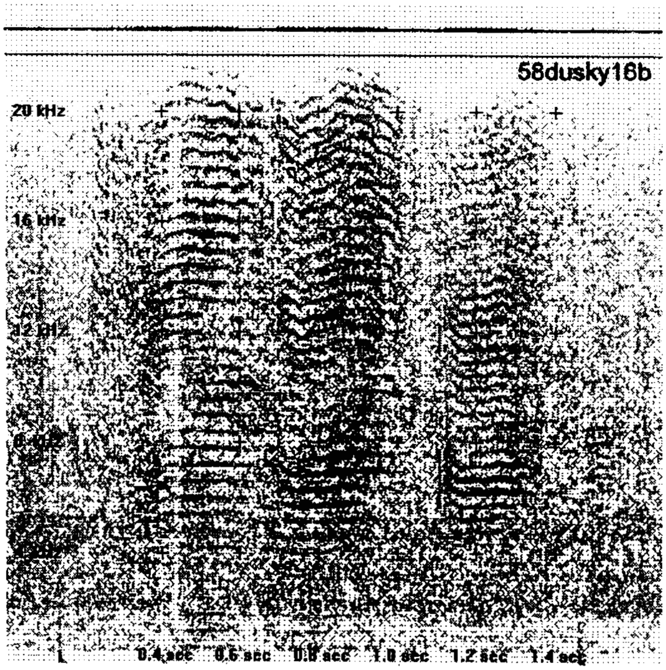


Figure 27 (a)-(b). Dusky dolphin (*Lagenorhynchus obscurus*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)



(b)

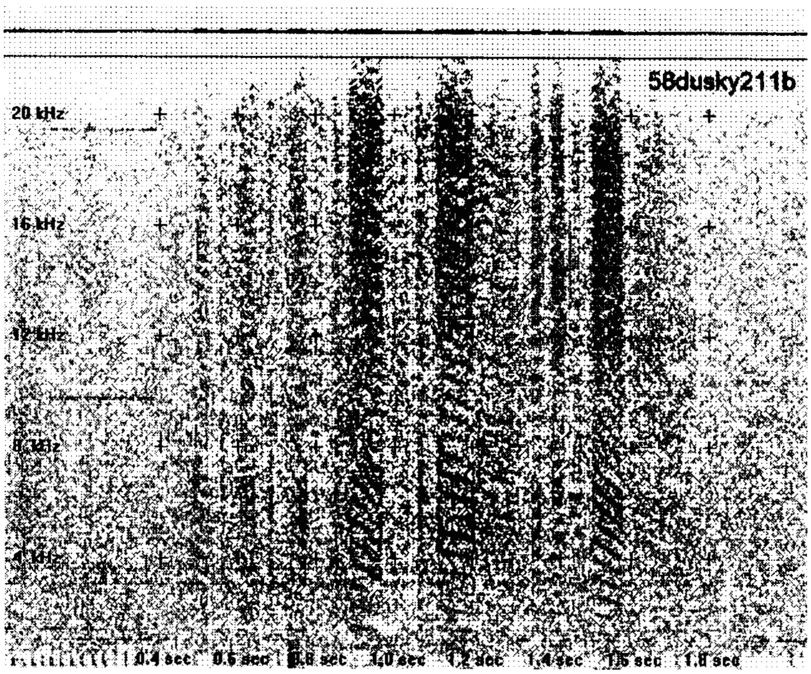


Figure 28 (a)-(b). Dusky dolphin (*Lagenorhynchus obscurus*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

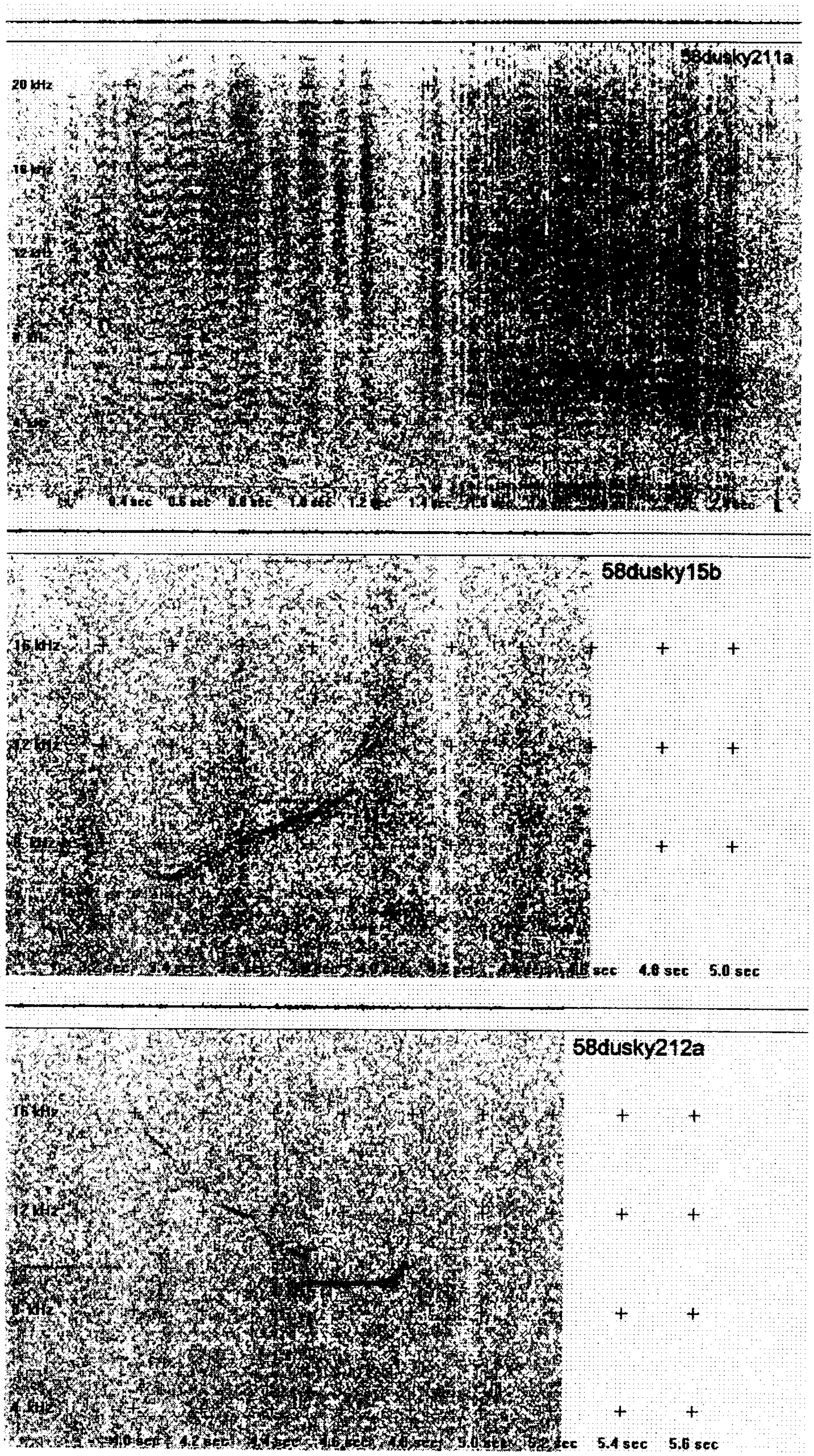


Figure 29 (a)-(c). Dusky dolphin (*Lagenorhynchus obscurus*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

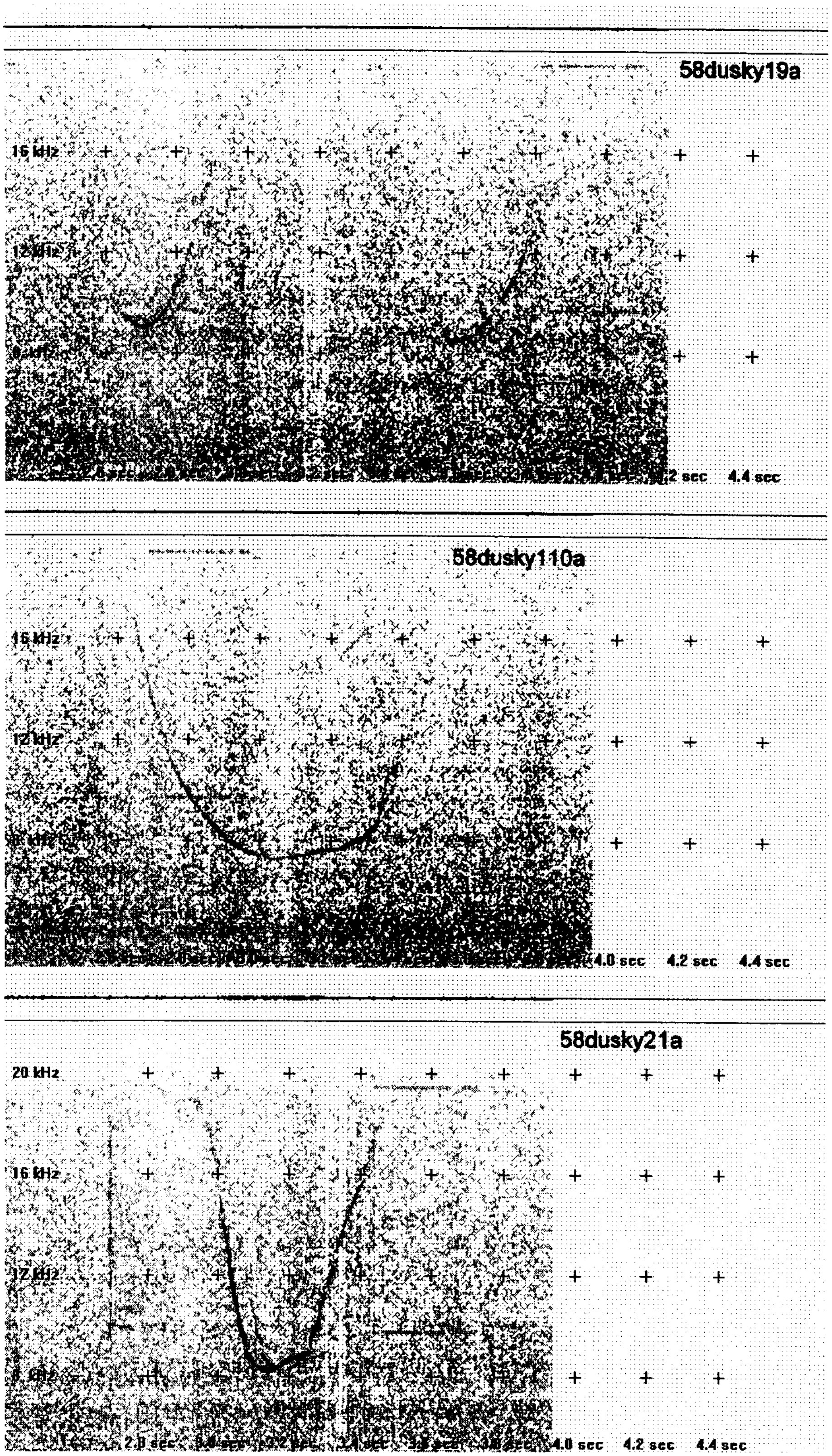


Figure 30 (a)-(c). Dusky dolphin (*Lagenorhynchus obscurus*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

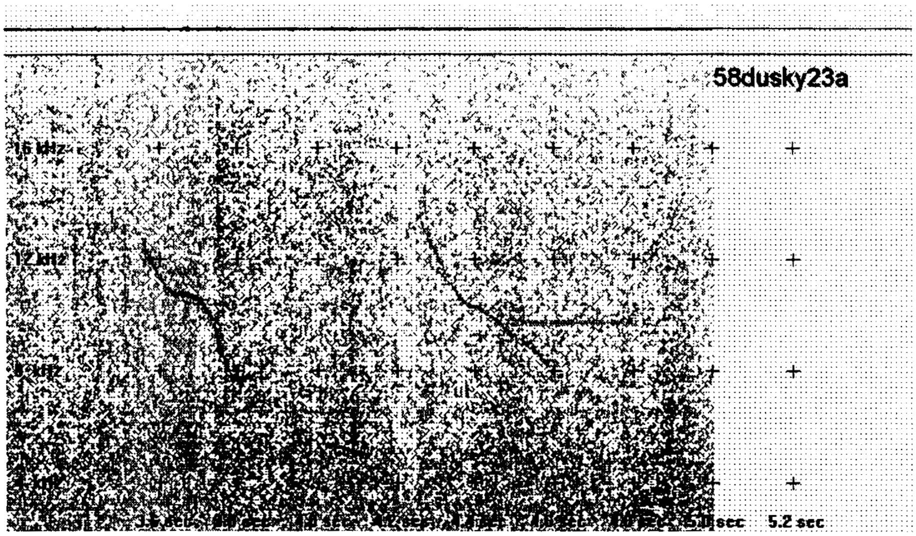


Figure 31. Dusky dolphin (*Lagenorhynchus obscurus*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given in Table 1.

(a)

(b)

(c)

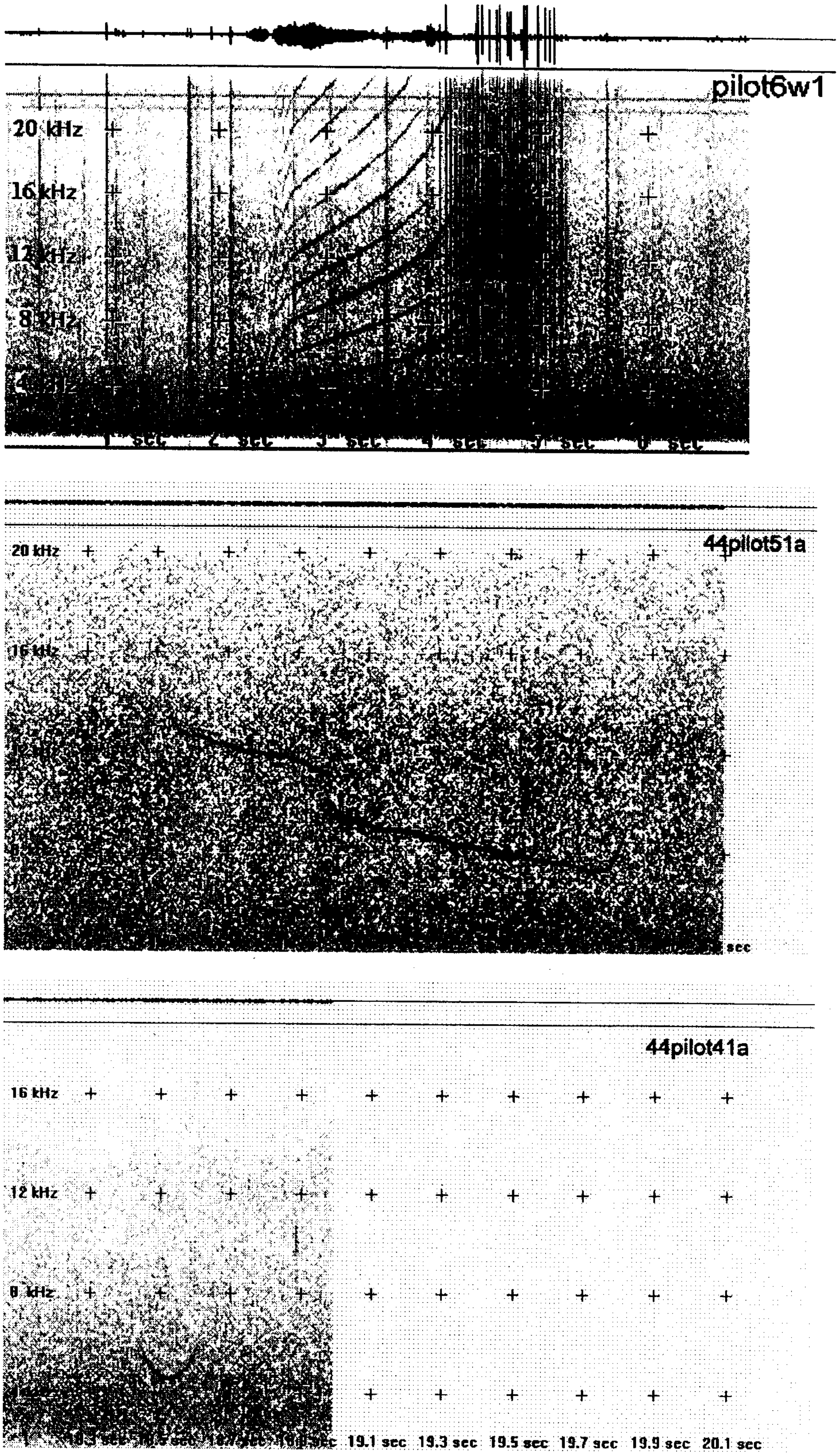


Figure 32 (a)-(c). Short-finned pilot whale (*Globicephala macrorhynchus*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

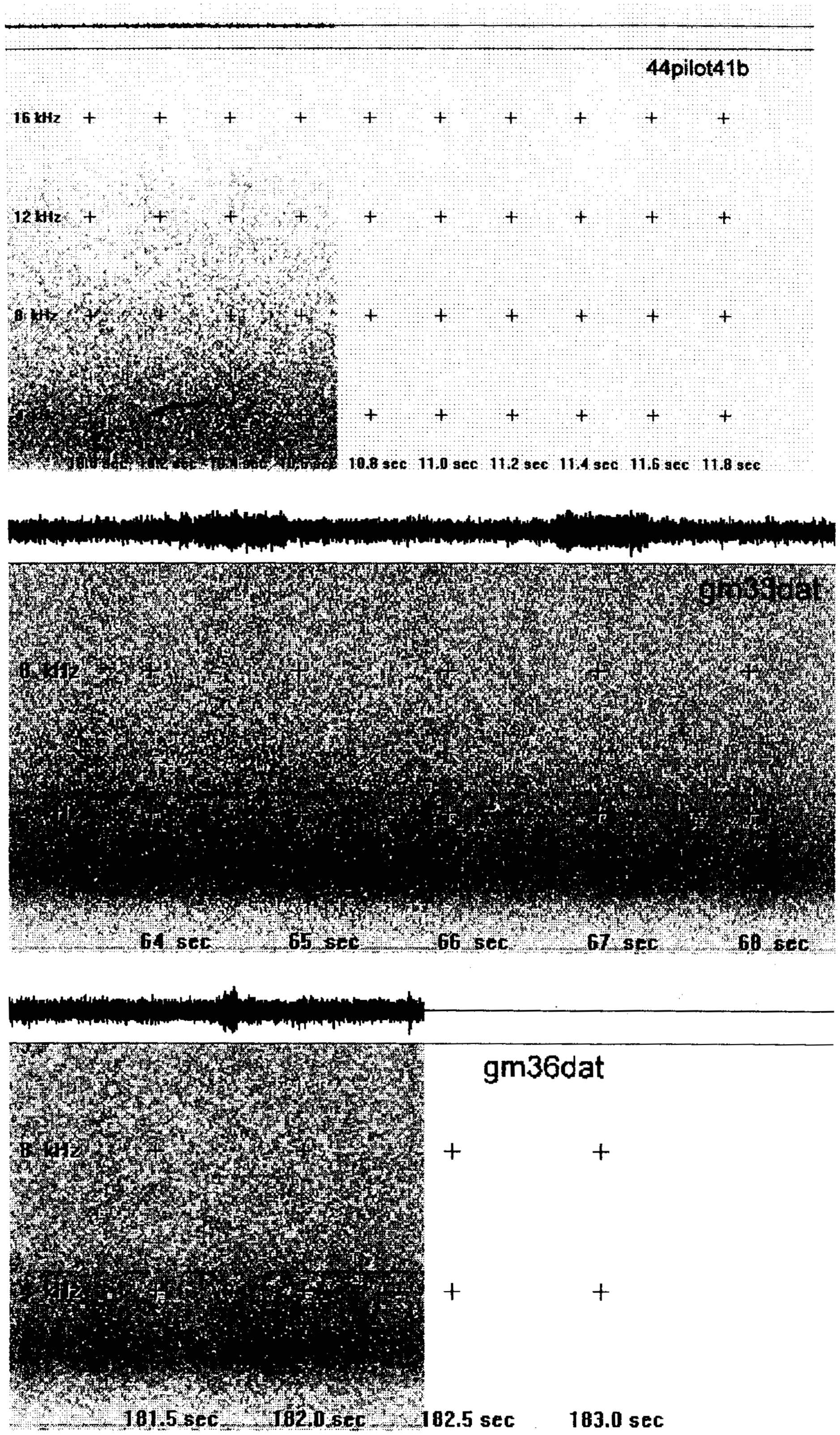


Figure 33 (a)-(c). Short-finned pilot whale (*Globicephala macrorhynchus*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

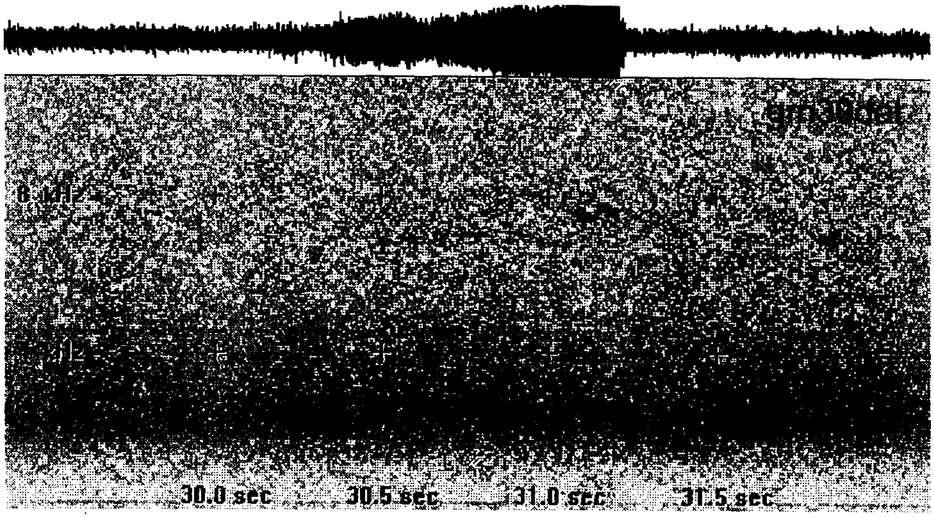


Figure 34. Short-finned pilot whale (*Globicephala macrorhynchus*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

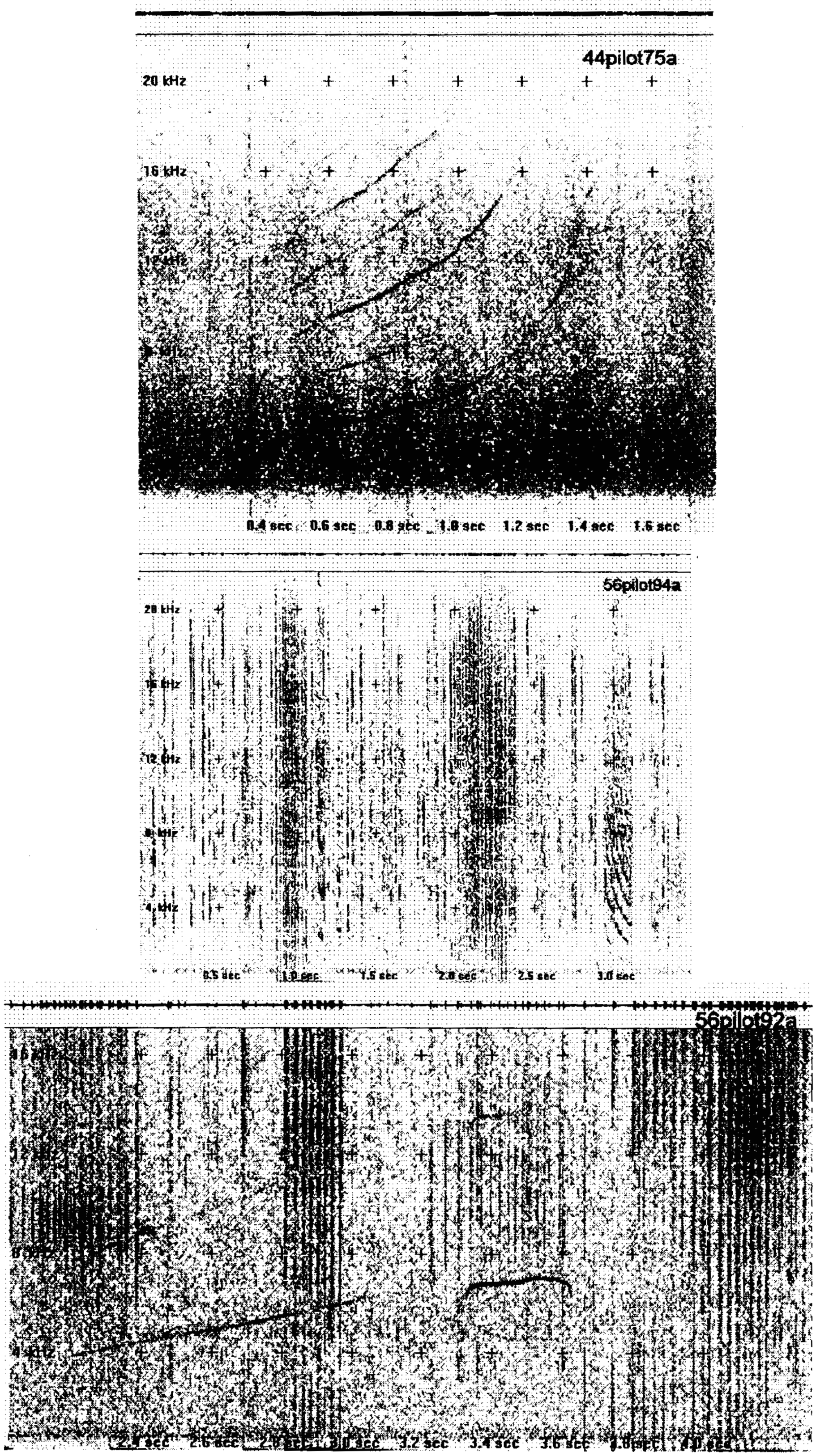
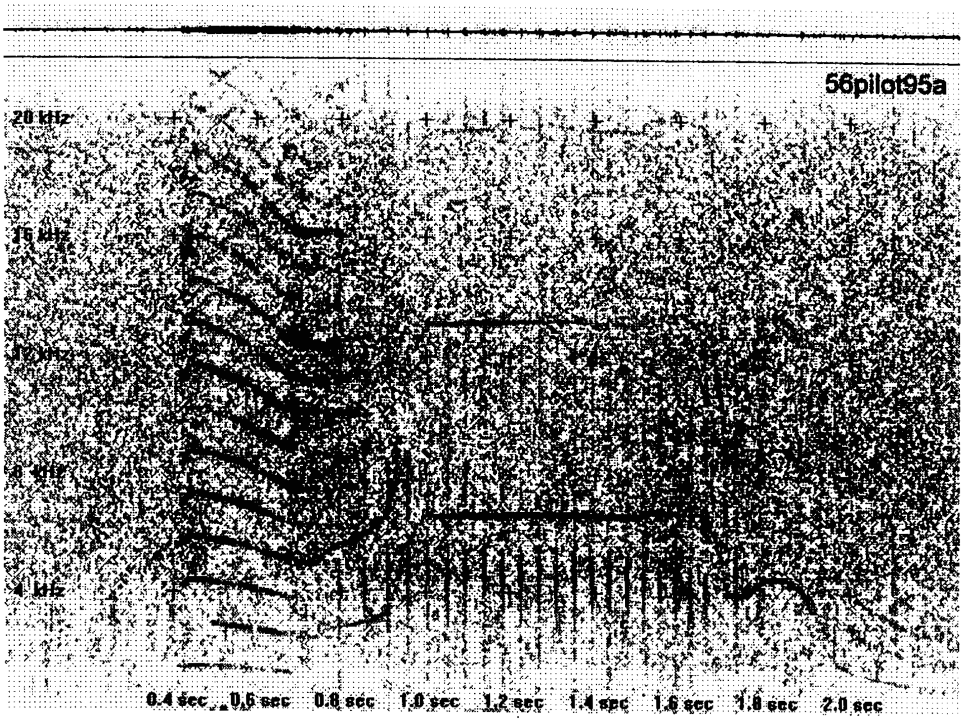


Figure 35 (a)-(c). Unidentified pilot whale (*Globicephala species*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)



(b)

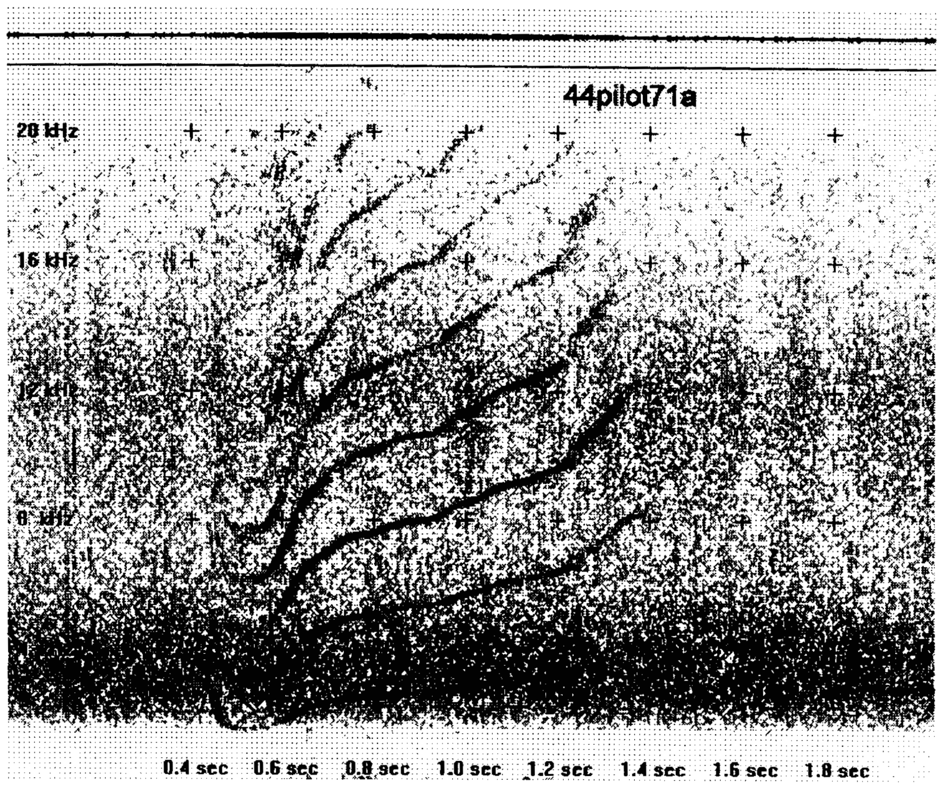


Figure 36 (a)-(b). Unidentified pilot whale (*Globicephala species*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

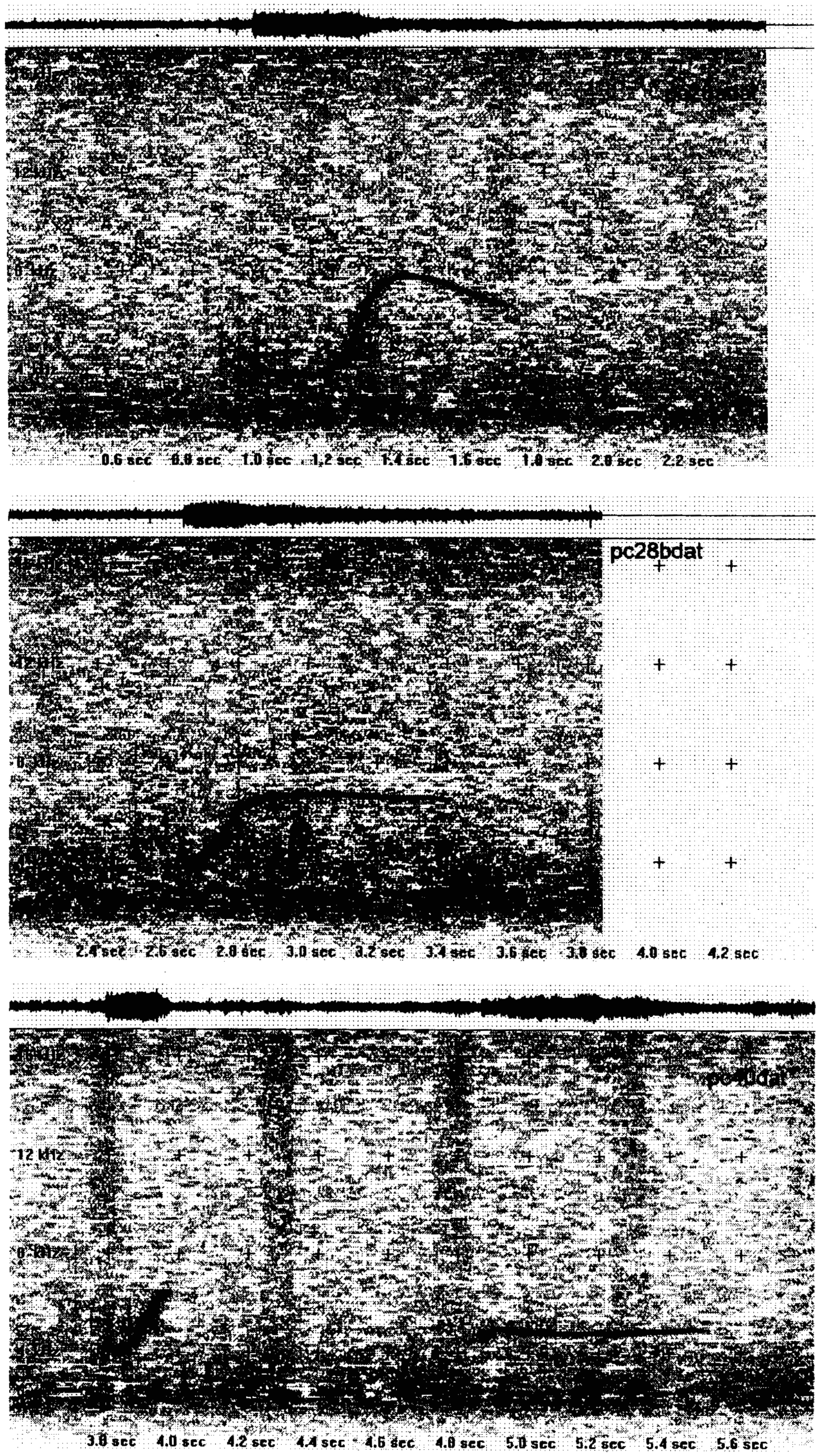


Figure 37 (a)-(c). False killer whale (*Pseudorca crassidens*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

(a)

(b)

(c)

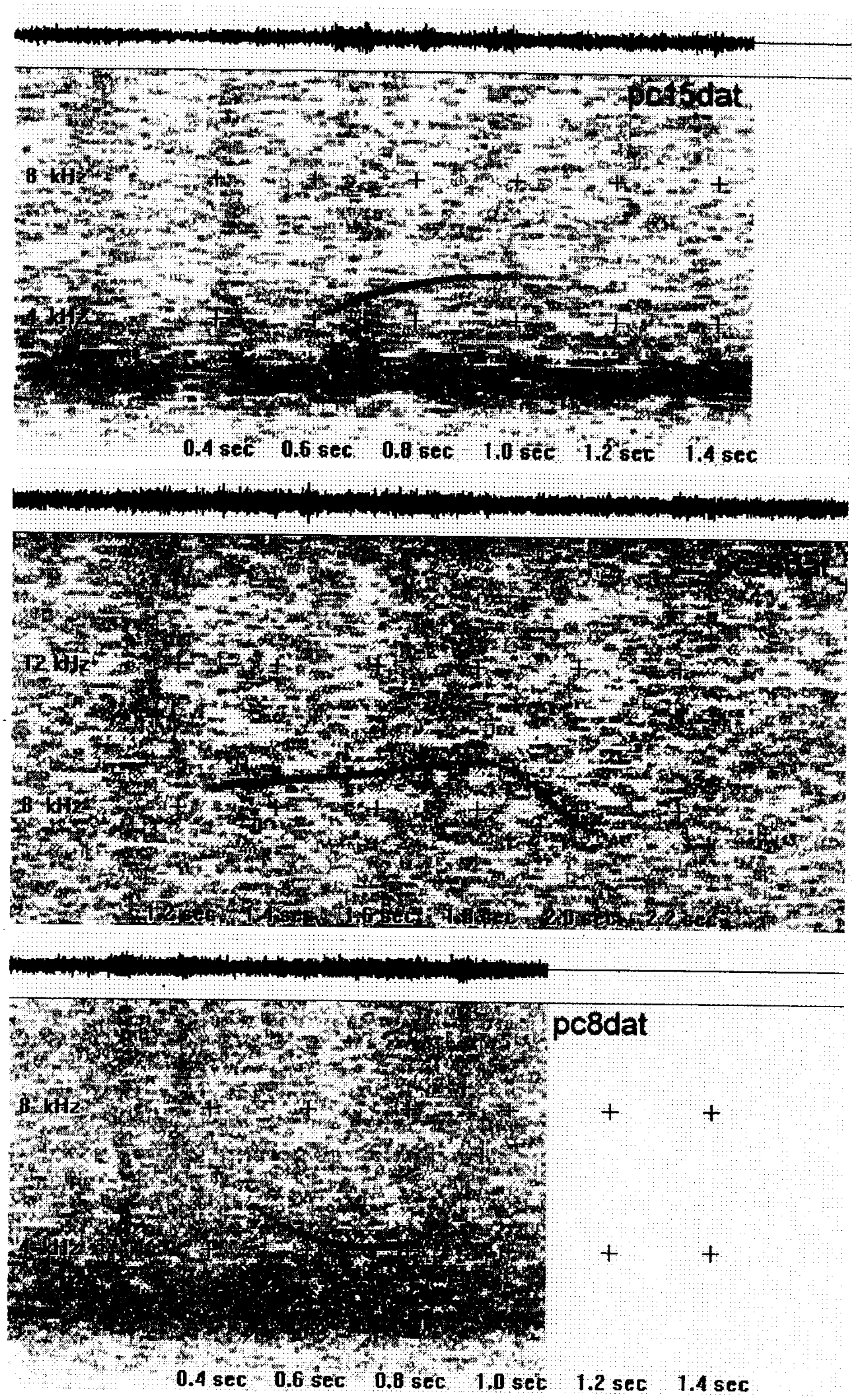


Figure 38 (a)-(c). False killer whale (*Pseudorca crassidens*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given for each spectrogram in Table 1.

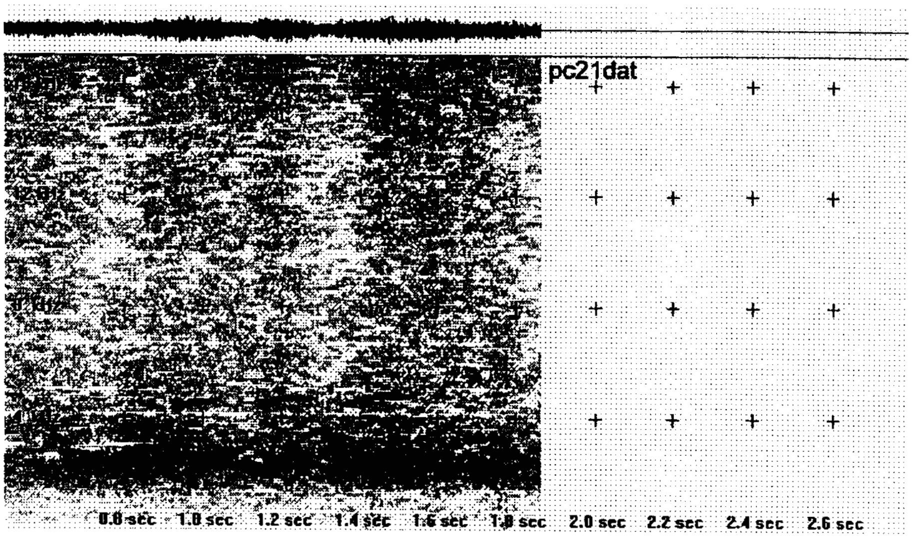


Figure 39. False killer whale (*Pseudorca crassidens*) vocalizations recorded in the Eastern Tropical Pacific Ocean. Sighting number, date, location, group size estimate, and hydrophones used are given in Table 1.